AUSTRALIA IN THE WAR OF 1939-1945

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CLINICAL PROBLEMS OF WAR

by

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". . . a clock strikes.
And all sway forward on the dangerous flood
Of history, that never sleeps or dies,
And held a moment, burns the hand."

(W. H. Auden)

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ABBREVIATIONS USED IN REFERENCES

Med. Journ. Aust.—The Medical Journal of Australia.

Brit. Med. Journ.—British Medical Journal.

Quart. Journ. Med.—Quarterly Journal of Medicine.

Lancet—Lancet.

Journ. Clin. Invest.—Journal of Clinical Investigation.

Arch. Int. Med.—Archives of Internal Medicine.

Br. Journ. Path. & Bact.—British Journal of Pathology and Bacteriology.

Br. Journ. Surg.—British Journal of Surgery.

Br. Journ. Derm.—British Journal of Dermatology.

Journ. Amer. Med. Assn.—Journal of the American Medical Association.

Aust. & N.Z. Journ. Surg.—Australian & New Zealand Journal of Surgery.

Bull. War Med.—Bulletin of War Medicine.

Ann. Surg.—Annals of Surgery.

Arch. Path.—Archives of Pathology.

Am. Journ. Hyg.—American Journal of Hygiene.

Trans. Roy. Soc. Med.—Transactions of the Royal Society of Medicine.

Trans. Roy. Soc. Trop. Med. & Hyg.—Transactions of the Royal Society of Tropical Medicine & Hygiene.

Postgrad. Med. Journ.—Postgraduate Medical Journal.

Bull. Trop. Dis.—Bulletin of Tropical Diseases.

Am. Journ. Trop. Med.—American Journal of Tropical Medicine.

Pract.—The Practitioner.

Aust. Journ. Dent.—The Australian Journal of Dentistry.

Journ. Path. & Bact.—Journal of Pathology & Bacteriology.

Brit. Journ. Ophth.—British Journal of Ophthalmology.

M.R.C. Memo.—Medical Research Council Memorandum.

Proc. Roy. Aust. Coll. Phys.—Proceedings of the Royal Australasian College Physicians.

Army Trop. Med. & Path.—Army Tropical Medicine & Pathology.

Surg. Gyn. & Obstet.—Surgery, Gynaecology and Obstetrics.

Brit. Journ. Exp. Path.—British Journal of Experimental Pathology.

PART I

MEDICAL

PREFACE

THIS book obviously cannot fully cover a subject so wide as the *Clinical Problems of War*; rather it is a brief and incomplete account of the medical and surgical problems of the Australian armed forces during the war of 1939-1945. The Australian Army Medical Corps[1] has supplied most of the information used in this volume, but the medical services of the Royal Australian Navy and the Royal Australian Air Force have also contributed to it, even where not specifically stated in the text. More detailed accounts of some subjects of special interest to medical officers of the navy and air force will be given in the individual histories of these services in a later volume.

The plan originally drawn up for an Official Medical History by the late Major-General R. M. Downes included clinical volumes. He intended that these should consist of articles written by medical officers, but even during the short time he worked on the history before his lamented death on duty, he realised that considerable difficulties would arise, and I have experienced these likewise. Such accounts could only be properly written with access to relevant records, and preferably during the officers' military service, but this was not practicable. Moreover, the claims of post-graduate study and of professional rehabilitation could not be denied. Therefore the actual writing of this clinical volume has, with the exception of a few sections, been a single-handed task.

The scope of the book calls for some explanation. It is not a text book, nor a military manual. It deals with military administration only where this is germane to the control of disease or injury. It does not pretend to cover the whole of any subject, but it records Australian experience, the methods found valuable, the successes and the failures. It stops short at the end of 1945, and it touches only the barest fringe of post-war experience, for this is beyond its ambit. The book must be read in the light of what we knew and experienced in the period of 1939-1945: it is complementary to the volumes in course of preparation, which will deal chiefly with campaign narratives and affairs of administration, and will also contain a quantity of clinical material illustrative of the problems of field work. This clinical volume will not rob the future volumes, but is designed to show how the doctor remains the doctor even in an environment largely foreign to him. I hope too that it will show how the Australian medical officer in time of war is still resourceful, apt at extemporisations, and able to make contributions of real scientific value to the problems that are his.

The medical histories of the 1939-1945 war compiled by English-speaking Allies have one unique common feature: they are coordinated by a Liaison Committee of Official Medical War Historians, a body which came into being through the foresight and wisdom of the British medical historical organisation, with representation from United Kingdom, Australia,

[1] Since the war the right to use the title "Royal" has been conferred on the A.A.M.C. which has thus become the R.A.A.M.C.

Canada, India, New Zealand, Pakistan, South Africa and the United States of America. These representatives have the status of appointment by their respective governments. This committee has held meetings in England, Canada, and Australia, has freely discussed the whole project, exchanged and criticised drafts, and agreed on certain principles.[2] From these discussions arose an important decision that the clinical volumes should have priority of compilation and publication, because of the urgency implicit in placing their conclusions before the medical world. In one sense history is never out-of-date, but if a history of this kind is to be valuable it should be available as soon as possible. It was also agreed that, while medical material was freely exchanged, subjects concerning which some services had little experience would only be dealt with briefly, leaving fuller expositions to those who could speak from personal knowledge and investigation. This will explain why in some instances there is unevenness of size in the various chapters.

In the early years no settled organisation was laid down for the Medical History, and I acknowledge with deep gratitude the help given by the Department of the Army, providing me with office accommodation in Melbourne and Sydney for 2½ years, and securing me the valued help of Lieutenant G. Cutler, A.A.M.W.S., as a research assistant in 1945, and Corporal D. B. Stinton, A.A.M.W.S., during 1945 and 1946, and Miss G. M. Jones, who carried out the secretarial work during 1947. I am most indebted to Colonel A. M. McIntosh, D.D.M.S., Eastern Command, who helped in many important ways while I worked in this area. Mr Gavin Long, the General Editor of the War History, has given me much valuable assistance and advice, and since coming to Canberra in December 1947 I have had useful help from his staff, particularly in access to non-medical, but essential information, and in typing when no other assistance was available. Mr W. A. McLaren, Secretary of the Department of the Interior, has been most helpful in securing working conditions necessary for the carrying out of this huge task. The director, Colonel J. L. Treloar, and the records and library staffs of the Australian War Memorial have also provided source material and literature. Since July 1949 I have had invaluable help from Mrs Evelyn East as a research assistant and from October 1949 from Mrs Gladys Pope in a secretarial capacity. At a time when it seemed impossible to secure adequate assistance Mrs H. W. Wunderly voluntarily carried out useful research for me, and helped me with critical reading of drafts.

Every section of this book has been submitted to the critical scrutiny of medical officers who had personal experience of the relevant subjects during the war, and who have furnished many valuable corrections, suggestions and material. I am specially indebted to Dr Mervyn Archdall, Editor of *The Medical Journal of Australia,* who read and criticised the whole typescript of this volume, and has given me the greatest help and encouragement.

[2] At the time of writing a final meeting is projected, possibly in India.

A large amount of material has been gleaned from articles already published; these contributions are acknowledged in the lists of references. A considerable bulk of material has been gathered from reports from medical units and from individual medical officers; with pleasure I acknowledge these, and also the myriad contributions made, often unknown, by hundreds of unnamed doctors on service, who have shown so high a grade of observation and skill.

Special articles for use in the history were supplied by several officers; my thanks are particularly due to Colonel I. J. Wood, Lieut-Colonel K. W. Starr, Lieut-Colonel B. K. Rank, and Major R. J. Walsh, who have enriched the sections on blood transfusion and surgery, and to Majors S. V. Marshall and J. F. McCulloch for supplying much of the material for the section on anaesthesia.

In accordance with the general policy of the Australian War History I point out that some material used in this book has been derived from my personal experiences while acting as the physician in charge of the medical division of the 2/1st Australian General Hospital, and of the 113th Australian General Hospital, Concord, and as a Consulting Physician to the army at the Australian medical headquarters and in the field.

Canberra, 15th June 1950. A.S.W.

PROLOGUE

WAR AND MEDICINE

I

BEFORE 1914 there were but the premonitory stirrings of the scientific revolution that has since changed so completely the outlook of clinical medicine. Young practitioners of that period hardly realised that even the clinical thermometer was a comparatively recent innovation, though they could remember in their own boyhood the world stir aroused by the modest Röntgen, and during their student years were perhaps vaguely relieved that there was no simple and reliable method of estimating the blood sugar content. No doubt they read of the slaying of an otherwise obscure Archduke at Serajevo without any prophetic insight; they could not have foreseen how the thunders of war would shake the world, nor did they realise how sweeping would be the changes in their own profession.

After 1918 the urge to test and to measure animated the clinician. Methods became less empirical and more scientific, though it has since been evident that science at the bedside cannot confine all man's variables within a formula or weigh the imponderable. Even romantics who find science a fairyland must admit that its explorers sometimes pay homage to the comfortable shrine of mechanolatry.

Of course there can be no doubt of the blessings brought by these changes, though we may at times regret that the centre of gravity of medicine has moved from the home to the clinic and the hospital. Here the great gifts of modern methods of investigation and controlled therapeutics can be applied with a maximum of efficiency and a minimum of risk. Indeed the latter is more important than ever; there are not inconsiderable hazards in the bolder explorations of the human frame and the undaunted use of more potent and more toxic drugs. Laboratory and clinical research have now so multiplied that no single mind can cope with them, even using the up-to-date and copiously documented reviews of current literature. Post-graduate study occupies a dominant position in medical education even during war, and is a reflex of the complexity of medical science today. So also is the growing recognition of the value of that rare type of person, the medical philosopher, who amid the clamour of technologists, sociologists, economists and politicians finds some pattern in the tangled skein. However efficiently the Norns of modern medicine subdivide their duties in the weaving of destiny, they still require an oracle.

This wave of change reached military medicine after some delay. In Australia the way of the few "regulars" in service medicine is hard. Medical administrators and advisers have difficulty in pressing the adoption of modern methods, and even during war the higher command is not readily convinced that the most recent advances are desirable or practicable. But a body of practitioners switched suddenly from their work in the civil community to service in the field helps greatly by its strong insistence on

carrying over the best of methods and equipment into active service. At times their zeal needs some restraint, but it is an active and powerful leaven.

A little before 1939 it would have been hard to predict universal micro-radiographic examination of recruits, or refinements such as electro-cardiography or bedside estimation of the specific gravity of the blood in medical units in the field. Nor would it have seemed likely that a medical research unit established to seek the solution of specific problems affecting an army in the tropics should also make contributions in the realm of pure science.

II

So much for the changes in scientific outlook of the medical profession in the years between the wars of 1914-1918 and 1939-1945. During this period signal changes had also taken place in the social, economic and political life of the community. It is of interest to see how far the medical profession, considered as a social group, had absorbed these elements of change, and how far it could still be recognised as a class somewhat distinctive in its ways of thought. The pomposities of the closing decades of the nineteenth century so clearly reflected in the social creeds, the literature, the art and the music of this period had largely disappeared by 1918, or were replaced by less obvious pretensions.

In these changes the medical profession, like other professions, had shared. The rise of specialism and of the scientific method now placed its internal distinctions on a firmer basis of special knowledge and special forms of practice. Medicine and surgery were further subdivided; between the extremes of specialisms the mutual links were few, but they were still strong, depending on the basic concepts of dealing with the sick in mind and body, and of a predominant interest in the individual patient.

Later in this period the upsurge of psychiatry, pre-natal care, child welfare, industrial medicine, and the establishment of chairs of social medicine brought a greater unity to the professional aims of a body whose work and interests covered a field at least as wide as that of any other scientific group. When closely examined this unifying influence still derived its strength from the firm individualism of physicians and surgeons. This theme underlay all clinical teaching. Even the jargon of the day which called a sick man a "case" emphasised his occupation of the focal point of attention. It is so easy to generalise on diagnosis or treatment, but so difficult to appraise the needs of one sick man. The importance of giving enough time, patience and attention to the eliciting of each man's story cannot be obscured by weighty investigations in the clinic or enthusiasms of "gadget-minded" doctors or public.

This has been all the more significant in the relations between members of the medical profession and the general community in an era when individual freedom is dwindling, and the right of conscience is belittled. As Constant Lambert has aptly said, the well-controlled citizen has become adapted only for "mass indignation, herd pleasures and community singing." His opinions are largely derived from Press, radio and public utterance, and while publicity in health matters from these sources is good

in principle, it remains so in practice only if properly used. Too often health as an entity is confused with matters such as the provision of facilities for diagnosis or treatment, whereas these are only part of the story. Even worse, positive harm is often done by publicising certain aspects of some subjects, such as neurotic types of illness. The average man's concern with health and illness has thereby become somewhat distorted. This is reflected in the universal aspirin in handbags or waistcoat pockets, or, sad to relate, in the too-prevalent barbiturates, and in the numerous proofs of self-drugging to be found in the sanctuary of the bathroom cupboard.

Nevertheless in health and sickness the emphasis remains on the individual, and in a world of failing individualism the medical profession stands out as one of the few social groups to champion the single soul. The stubbornness of this tenet has made doctors as a class somewhat intransigent of changes in which their life and training enable them to look past immediate expediency to the dangers of non-conformity with natural law. This applies with particular force to those medical men and women whose overall knowledge of medicine is widest, whose capacity to serve the public is greatest, and who are of the greatest value to the community in peace and war, the general practitioners.

III

This then was the problem facing the civilian medical profession involved in the turmoil of war. How could its members best bring their highly individual application of scientific method to national service, how fit into the ordered hierarchies of the state and the armed forces? This story can best be told by following the adaptation of medical organisation and method to the exigencies of training and campaigning, and describing how the wastages of war could be minimised and controlled, and how its asperities could be softened. This leads us into a ramification of administration which stretches from a central directorate through many, sometimes only too many, sub-directorates to units contrived for several purposes, yet always for the one great purpose, and finally to the individual plain doctor plying his uniformed calling in a manner consonant with his training and his instincts. The background of this complex organisation is set by its last component, the practising doctor. Some of the problems met with on active service were identical with or similar to those of civil life, some were unfamiliar. Many were difficult, their solution depended on observation, experience and experiment: research must begin in the front line.

Therefore it is logical that a medical history should begin with an account of the purely medical problems of doctors on service. When they stepped from civil or peacetime practice into the theatre of war what did they bring with them, and later when they stepped back into a world crying for reconstruction, losers in some things, gainers in others, what did they bring with them then?

It is fitting that those physical and mental trials which beset the service man and woman in war should have priority of record in a medical

history. Let us not forget that, as Rudyard Kipling once pointed out to a gathering of medical men, mankind may be divided into two classes, doctors and patients, and that without the cooperation, cheerfulness and fortitude of the patients the efforts of the medical services would have been of less avail.

SECTION 1—INFECTIOUS DISEASES

(a) Alimentary Group

CHAPTER 1

BACILLARY DYSENTERY

WHEN units of the Second A.I.F. were despatched to the Middle East early in 1940 it was recognised that dysentery would constitute a major problem as it was endemic there both in mild and dangerous forms. In addition to hospital facilities, provision was made for the pathological diagnosis of dysentery as well as of malaria, by the issue of special diagnostic panniers for mobile medical units. During the 1914-1918 war there seems little doubt that confusion sometimes occurred between bacillary and amoebic forms of dysentery, but the extension and wide application of cytological studies which became important during that period made this unlikely in 1940. Moreover, knowledge of the cultural and immunological properties of dysenteric bacterial groups had greatly advanced. Nevertheless practical knowledge of the disease among Australian physicians was not as full as was to be desired, because, in spite of the fact that it is mildly endemic in many parts of Australia, there still was a tendency to regard it as an exotic disease.

When the first troops arrived in Palestine not even the cold weather nor the efforts of hygienists could prevent the rapid appearance of mild bacillary dysentery. From that time until the general demobilisation dysentery remained an active problem, usually well under control, but prone to take advantage of any hygienic slip by outbreaks that were mostly minor but, on occasion, severe enough to menace manpower. Fortunately it was largely mild in type on all fronts, but it could easily have been a waster of armies and a greater cause of loss of life.

CLINICAL FEATURES

The clinical picture followed well recognised patterns, which were clearly set out in technical instructions issued by the Australian Medical Services in the Middle East, and also in accounts published by Australian medical officers. It is significant that the first four medical instructions issued in the Middle East dealt with the dysenteries. Slight differences were observed in the relative prevalence of certain symptoms in various outbreaks, but there was no significant variation in the general picture presented in different areas. Extreme variability was found in the severity of the disturbance in different individuals, the attacks ranging from unrecognised infection as shown by some proven carriers, or the most trifling of intestinal upsets to a rapidly fatal illness.

The onset was usually abrupt. Some observers, such as Hone, Keogh and Andrew found that a slight brief rigor was common, others, like

West, that this seldom amounted to more than a slight shivery feeling. Abdominal discomfort was always present, usually beginning as colic, later being more general. In all but the mildest attacks some degree of constant abdominal pain was felt, most frequently in the lower central regions, and often associated with tenderness. This tenderness was chiefly in the lower part of the abdomen and rather more persistent and noticeable in the left iliac fossa than the right. Nausea occurred in about half of the cases, but vomiting, though noted in as many as a third of the cases in some series, was not a common or conspicuous feature. Tenesmus was often troublesome, sometimes being associated in worrying peri-anal pain and soreness.

One diagnostic difficulty was the distinction between acute dysentery and appendicitis, though this was more likely to arise with amoebic dysentery. Not a few surgeons were at times misled by the sudden febrile onset, by the abdominal pain and tenderness especially if in the right iliac fossa, and by the confusing latent period before diarrhoea began. Rose has pointed out that true appendicitis with diarrhoea occurred in the tropics, and that instances of dysenteric appendicitis were occasionally seen. Indeed it is possible that this occurs more frequently than is realised, for if the appendix can empty, its concomitant inflammatory changes may subside as the dysentery subsides. In Nakom Paton in Thailand, appendicitis was observed in much higher proportion in dysenteric wards than in others (see section on amoebiasis). By contrast, a clinical impression gained from the later years of war in the Pacific Islands was that, considering the high incidence of bowel infections in soldiers, appendicitis was less often encountered than might have been expected. It was then no more common than in the civil community; this may well have been due to the protective anti-bacterial action of sulphaguanidine. Repeated observation was found desirable when this complication was suspected, for, while an acutely inflamed appendix would be dangerous to leave, and while it may do no harm to remove a hyperaemic appendix from a patient in the early stages of a toxic dysentery, an added burden is imposed in an uncomfortable disease.

In the more toxic forms of dysentery muscular cramps occurred, especially when dehydration was a feature of the attack. Toxic symptoms of a general order were also common, such as headache and malaise, amounting to prostration in acute infections. Some fever was usual, seldom more than slight, though it reached 103°F. in the early stages of some severer attacks. More significant of severe toxaemia was a subnormal temperature associated with signs of collapse. The one universal symptom was, of course, diarrhoea, which appeared after a latent interval varying from a very brief period to twelve hours or more. Rarely the onset imitated certain forms of food poisoning: in a few observed series the simulation has been close, with sudden simultaneous affection of a number of men with vomiting and diarrhoea. The duration of this latent period was in no sense a guide to the possible severity of an individual attack. Neither was the intensity of the early toxic symptoms of onset an accurate index of the expected duration or degree of the illness. The frequency of the

diarrhoea was roughly an index of the severity. It was found that in general a high stool frequency, say, over fifteen per day, was associated with a more toxic and sustained attack. Sometimes the number of motions per day reached thirty or forty, but this was unusual. The fall in the rate was usually a fair index of clinical improvement.

Shiga dysentery in its more toxic and dangerous forms was characterised not only by more severe manifestations and a longer illness, but also by its insidious nature. Pain often increased over the first few days; vomiting might occur a day or two after the onset; and blood in the motions, usually an obvious feature, might persist or increase. Such signs, together with an increasingly severe toxaemia, formed a characteristic crescendo due to the increasing necrotic damage to the mucous membrane of the colon typical of this form of the disease. Circulatory failure, coupled with dehydration and signs of renal failure, appeared in the most severe Shiga infections, and were a feature of some fatal cases. This description refers particularly to the dangerous illnesses due to the Shiga type before the advent of sulphaguanidine and other similar drugs, now fortunately rare. In some instances death could occur quickly: a British surgical consultant soon after arrival in Egypt in 1940 contracted a severe Shiga dysentery, and died after some days despite the most skilled and assiduous attention. On the other hand, it is important to realise that Shiga infections may also be mild for there was a real danger of such attacks becoming established unless vigorous treatment was promptly carried out.

Anxiety was felt occasionally with acute attacks of the Flexner type, but usually only for a brief period. Provided that the patient's nutrition was good and that he was not debilitated by exhausting combat or other conditions or by intercurrent disease, and that good attention could be ensured, it was seldom necessary to place him on the "seriously ill" list. The combination of certain diseases was apt to be serious. Dysentery and diphtheria have together been responsible for death on a number of occasions. Dehydration was always of potential importance, especially when enhanced by the climatic conditions in which many attacks were encountered. When men had already been subjected to hardship and suffered from some degree of lowered nutrition, dehydration readily became significant, and toxic effects were magnified. This was strikingly seen in the Owen Stanley engagement in New Guinea. Indeed the generally mild nature of dysentery as seen in well-equipped medical units was apt to be misleading. Dysentery could easily have reduced to impotence the forces on the Kokoda Trail in New Guinea had not special measures been taken, as will be presently told. Dysentery did kill large numbers of British, Australian and Allied men in Japanese prisons and working camps, not so much through lack of therapeutic agents, but through concomitant malnutrition, exhaustion and disease.

As a brief digression, let us see what dysentery did under these conditions. Before hostilities began in Malaya dysentery was negligible. Just before the capitulation of Singapore it began to appear under the influence of adverse military conditions, with their reflections on nutrition and

hygiene. As troops arrived in Changi the infection intensified, reaching its peak in March 1942. In the first twelve months of captivity 2,939 A.I.F. men were admitted to hospital for dysentery, an average incidence of 250 per 1,000 per year, with 23 deaths. During the first two months one-eighth of the Allied troops were admitted with dysentery with 58 deaths. With a steadily applied hygiene campaign the incidence fell. In some of the working camps on the Burma-Thailand railway during the early period dysentery was reported as the chief killer, especially among the British and the Dutch. In these prisoner-of-war camps during the first half of 1942 the principal diseases were deficiency diseases and dysentery, and in "F" Force the appalling death rate of 3,000 men out of 7,000 was in part due to the effect of bacillary dysentery on undernourished men worn out by inhuman treatment and intercurrent disease, particularly malaria. At Chungkai 718 men contracted bacillary dysentery and 129 of these died, out of a total number of 1,237 who died from all causes. At Tavoy, Thanbyuzayat, Hlepauk and Retpu 125 men died of dysentery out of a total of 2,812 medical admissions, while even under the better conditions of Nakom Paton 40 deaths occurred from dysentery among 1,473 admissions. By contrast out of 3,806 cases of dysentery in the Middle East before the introduction of sulphaguanidine there were only 5 deaths. During the years 1939-1946, 21,015 Australian soldiers suffered from bacillary dysentery, but only 21 died, and some of these had other intercurrent diseases.

To return to purely clinical considerations, the incubation period was not found to be of great importance, observations suggested a much shorter period than that sometimes given. There seemed little doubt that the period was not more than twelve hours in some acute cases. An instance occurred of a voluntary though unwise experiment by a laboratory technician in a field unit who produced dysentery in himself ten hours after swallowing an emulsion of an organism unagglutinable by the polyvalent Flexner serum available, and thought perhaps to be non-pathogenic, but later found to be Flexner type VI.

BACTERIOLOGY

The bacteriological classification adopted in the Middle East and mainly adhered to throughout the war followed that of Colonel J. S. K. Boyd, whose work in typing dysentery bacilli in India was well known and who acted as Consulting Pathologist to the British Forces in the Middle East. The Shiga and Schmitz types were culturally distinctive, being non-fermenters of mannitol. The Schmitz type did not cause attacks of such severity as Shiga, though the latter sometimes gave rise to only mild illness. Localised outbreaks were occasionally found to be due to Schmitz type. The mannitol-fermenting organisms included the Sonne type, a late fermenter of lactose, and numerous other members of the Flexner and Boyd types which did not ferment lactose. The Sonne group was found to be responsible for certain outbreaks in Australia. The Flexner group, comprising types I to VI contained a group antigen, but the Boyd group had no group antigen. Three Boyd groups were recognised at first, but on later

evidence the so-called type P274, whose pathogenicity had been doubted, was accepted as Boyd type IV. The remaining heterogeneous type D19 was not found important in Australian experience. The recognition of these varied types made considerable calls upon field laboratories, especially as monovalent type sera were needed for the agglutination tests. Boyd's presence in the Middle East was not only of great help in the matter of advice, but he also made available specimens of test sera. Pathologists were often obliged to describe dysentery bacilli as inagglutinable owing to the difficulty of maintaining supplies of active test material in distant areas. It must be remembered too that much of this work was carried out under field conditions with restricted equipment and assistance, and often primitive housing. Major K. B. Burnside, working with the 8th Division in captivity, remarked that the making of cultures and subcultures in the open was "difficult", surely an understatement.

The chief concern of pathologists in the investigation of dysentery was to secure fresh material. Dysentery wards were sited as close to the laboratory as convenient and ward arrangements organised so that specimens were sent for examination without delay. The use of buffered glycerine-saline solutions was found of value where delay might occur, and this method was found to preserve specimens satisfactorily. It was not found difficult to train nurses and orderlies to select suitable specimens, containing mucus and as little faecal material as possible, and to despatch these to the laboratory with the relevant clinical data. Containers such as waxed paper cups with lids were found convenient, and a sterilised spoon or similar implement was used to collect the sample. At the same time specimens were collected for macroscopic examination by the medical officer. Extemporised methods were used for keeping these samples without risk of spreading infection, but even such apparently crude containers as cigarette tins, kept in fly-proof boxes, proved satisfactory. The observation of steady progress as evinced by the change from the serum-like early stool, with blood and flakes of mucus to the blood-free and finally the normal specimen was found of at least equal value to other clinical data, and represented an advance on the methods of many civilian hospitals.

Microscopic examination was also of value, though it did not always accord with clinical findings, as might be expected from the pathologists' limited opportunities for observation. The terms "bacterial exudate" and "indefinite exudate" were in general use. The former denoted a highly cellular fluid, containing up to 90 per cent polymorphonuclear cells, mononuclear monocytes and red blood cells. The latter denoted a mucoid secretion with scanty pus cells and a few red cells. While this might be consistent with a bacterial or protozoal infection the "bacterial" exudate was regarded as the typical product of bacillary inflammation of the colon. Though these findings added little to knowledge gained by clinical means, microscopic examination was of value not only as a confirmatory method but also for the added information it could give as to the presence of amoebic infection or of other parasitic infestation. The names "bacterial exudate" and "indefinite exudate" are open to objection; it is sometimes

forgotten that they described the appearance of only one microscopic specimen.

Cultural and serological methods were used in addition in all cases of importance, such as those of particularly severe type, or those suggesting the need for epidemiological investigations. They were essential in enquiries into localised or extensive outbreaks of dysentery. The medium used at first was the original McConkey medium—later the newer selective media were made available. Leifson's medium, desoxycholate-citrate agar, was found very valuable. Ferris and Fortune in reporting their work to the Allied Malarial Control Conference in New Guinea[1] found that this was the most satisfactory medium for use with rectal swabs, though it had the disadvantage of tending to inhibit Shiga strains. The Shigella-Salmonella was found one of the best of the newer media; Kligler's medium was used also for its selective value, and also Wilson and Blair's rosolic acid medium, though this inhibited the Boyd type IV. The original McConkey was not outmoded by any means, for busy pathologists prized methods productive of vigorous growth of these delicate organisms. Clearly differentiated colonies could sometimes be picked off and tested directly for agglutination against type sera. More often, however, subculture was necessary. Polyvalent group sera were not always found reliable, but difficult strains could always be referred for elucidation to headquarters in Melbourne from units in Australia or the Islands.

Exact figures of the relative frequencies of these bacterial types cannot be given fully. Field conditions often make it difficult to carry out investigations sufficiently early to be of value. In general the earlier cultures were made in the course of the disease, and the more acute the infection, the greater the chance of success. Further, conditions governing evacuation of the sick often made it necessary to stage or to hold men at units where full pathological facilities were not available. War experience has shown the great value of having adequate facilities for diagnosis available within practicable reach of the more forward units. In general the Flexner groups occurred most frequently, as might be expected. Hone, Keogh and Andrew in the Middle East found that out of 188 successful cultures 78 per cent were of Flexner type, and about 7 per cent of Shiga, Schmitz and Sonne, the Flexners being predominantly types I and II. Andrew in a New Guinea series found 80 per cent Flexner, 33 per cent being type VI and 5 per cent Shiga. This percentage of the Shiga variety represents the usual finding in infections occurring as outbreaks of endemic dysentery. The rates of incidences per 1,000 recorded in 1941 in the Middle East were dissected as follows: bacillary 8.91, Shiga 1.31, Schmitz 0.86, Sonne 0.38, Flexner 6.54, Boyd 0.04, and unspecified 12.98. The relative figures for Shiga and Flexner infections did not vary greatly in the Middle East, the proportion being 1.3/6.5 in 1941, and 2.3/5.65 in 1942. In Australia the Shiga/Flexner proportion was 0.13/1.03 in 1943 and 0.057/0.333 in

[1] This valuable body discussed many other topics besides malaria and it not only maintained a high standard of scientific communication by Australian and Allied medical officers, but did much to disseminate sound doctrine in preventive medicine and to foster its practice.

1944. In New Guinea the figures were 2.04/6.26 in 1943, 0.716/3.95 in 1944 and 0.221/2.13 in 1945. At the 2/9th Australian General Hospital in New Guinea in 1942-1943, over a period of eighteen months, 13 per cent Shiga were found and 78 per cent Flexner. This undue proportion of Shiga was probably due to the introduction of this type in large numbers by the Japanese. It was known to occur among their troops on the north coast of New Guinea, and Australian and Allied troops had to enter and hold areas fouled by the previous occupiers. The Japanese treatment was also inadequate, usually consisting of the giving of creosote tablets and charcoal and the use of tannic acid enemata. Later, also at the 2/9th A.G.H., Ferris and Fortune, using the examination of rectal swabs as a diagnostic method, found 13 per cent Shigas. Usually in the Pacific Islands campaigns the Flexner and Boyd types made up the majority of organisms isolated. Thus at Jacquinot Bay where a sharp outbreak occurred, 74 per cent of types isolated were of Flexner varieties. Sonne and Schmitz types were also found in localised outbreaks. Rothstadt, Fenner and Baker collected a series in central Queensland in which out of 288 patients admitted to hospital for diarrhoea 85 were bacteriologically proven to have bacillary dysentery, and of these 42 were of the type P274, found by Boyd in India, and later also in Egypt. The illness caused was of mild to moderate severity and was clinically indistinguishable from the Flexner type. Differentiation was made by using monovalent serum obtained from Boyd, who by personal communication confirmed the increasing incidence of this type in the Middle East. Whether it was already in Australia or was brought by carriers, it is now known to exist there. There can be no question that this organism is pathogenic.

Attempts have been made to correlate the features and severity of the clinical disease with the bacteriological types found by culture. These have not met with much success. In general a series of attacks due to the Shiga type will probably include a higher proportion of severe illnesses, but very severe attacks may be due to other groups. In military experience Sonne and Schmitz have been found capable of causing mild epidemics, but they may be more malign in the civil community among children or enfeebled persons. An impression was gained in Palestine that some Schmitz infections were inclined to be persistent, but no such generalisation can be established. This type of dysentery was common in Changi, Singapore, in 1944. In New Guinea Fortune and Ferris found from an analysis of 503 consecutive cases of diarrhoea that 18 per cent. of the Shiga infections were severe, 41 per cent moderate and 41 per cent mild, while the corresponding figures for the Flexner groups were 6 per cent, 35 per cent and 59 per cent. Especially since the introduction of sulphonamides into the treatment of bacillary dysentery, a diagnosis of the bacterial type by clinical means is much more likely to be wrong than right. Successful cultures may be made soon after the administration of initial doses of sulphaguanidine to patients with "clinical dysentery", but if there is delay in the taking of specimens adequate doses will jeopardise subsequent stool cultures.

The term "clinical dysentery" has been found useful, meaning that the diagnosis is made without pathological evidence, and implying an acute diarrhoeal disease in which mucus and blood are present in the stools. There is one drawback to the term, that it may encourage the false assumption that without these signs a dysenteric infection does not exist. This is quite false, as modern work with the newer selective media shows, especially in surveys for carriers.

As the war went on improved treatment and better hygienic control were gained over dysentery, more and more mild attacks were seen in proportion, whose aetiology could not be established by culture. The prompt response to routine therapeutic measures made it reasonable to believe that these attacks were due to a true, though attenuated, dysenteric organism. More work is needed on this problem. There was nothing in the Australian experience to suggest that they were due to a virus infection. Such an infection seems to be responsible for certain world-wide epidemics of gastro-intestinal disturbance, but their character has been different from the milder attacks familiar in the services, and their response to sulphonamides different.

SIGMOIDOSCOPY

Finally the importance of sigmoidoscopy must be mentioned. This attained the status of a routine diagnostic and prognostic method in the Australian medical services largely owing to the insistence of Fairley. It was of course no innovation, but from being a special technique used by few it became an essential and universal method in hospitals. In the beginning a sigmoidoscope was part of the surgical equipment, used only by surgeons, or lent as a concession for use in medical wards. But its value became so apparent in the Middle East that a sigmoidoscope was supplied to the medical division of each hospital, and medical officers working in dysentery wards became proficient in its use. A brochure on sigmoidoscopy was circulated to all medical officers, describing the standard method and the usual findings in pathological states. Its chief uses were to check the process of healing, as part of the standard of cure, the detection of carriers and a guide to further treatment and in the diagnosis of amoebic infections. The technique usually followed was the introduction of the instrument in the knee-left shoulder position with the body flexed, or in the knee-chest position. Preparation of the patient was found to be unnecessary. Little difficulty was found in passing the instrument up to the 20 centimetre mark and the 25 centimetre mark could be reached in most cases; inflation of the colon was seldom necessary. Sigmoidoscopy was not used during the early acute stages; pain and tenderness were thus avoided. A long swab stick of stiff wire, a small spoon on a long handle or a sucker device was used to collect material from ulcers or erosions of granular areas, mucoid secretion being selected for examination. With a table in an annexe or screened recess and simple equipment for sterilisation a number of men could be examined in a very short time. The use of this routine in dysentery wards has been found to be accepted readily by the patients, who soon recognise the value of the procedure and

its simple nature in skilled and gentle hands. Sigmoidoscopy was found of great value in Australian hospitals under Japanese occupation, particularly when bacteriological diagnosis was impracticable through lack of supplies and equipment. In subacute and chronic cases the information gained was particularly useful. At Nakom Paton in Thailand, where a huge hospital base was established with very slender equipment, a sigmoidoscope was extemporised from available material.

A development of the method has also been used in early bacteriological diagnosis by the method of the rectal swab. Ferris and Fortune in New Guinea successfully employed this diagnostic technique. They first introduced a swab through a guarding tube, but later swabbed by vision through a short proctoscope. They found this method was free from any but slight discomfort, and by selecting mucoid secretion from the rectal wall and avoiding faecal material obtained a high proportion of successful cultures. In a series of 78 patients cultures by swabbing were obtained in 74 instances, but in only 60 by culture from the stools. The picture seen by sigmoidoscopy in bacillary dysentery showed all gradation from slight hyperaemia to a severe coagulation necrosis. Fortunately for the validity of this method the changes seen in the rectum and sigmoid colon have been found to represent with a high degree of accuracy the type and amount of affection of the whole lower bowel. In sharp attacks during the active phase hyperaemia may be intense, mucus is abundant, and the mucosa is fragile and bleeds readily. Ulcers are often seen later. These are usually multiple and quite small, arising from the crypts. An intermediate stage of retention cysts may be seen, which appear as raised yellowish swellings a few millimetres in diameter. Later the mucous membrane covering these breaks down to form ulcers. Haemorrhages may be seen in the submucosa, and the whole wall of the bowel is usually thickened and oedematous with adherent small flakes of fibrin and mucus. Sigmoidoscopy as part of the test of cure was perhaps one of the most important aspects, as potential carriers could thus be controlled.

COMPLICATIONS AND SEQUELS

The complications of dysentery were comparatively few. Detailed accounts of the most important complications and sequels were given in the early technical instructions to the A.I.F. in Middle East. In these the importance of the Shiga type was stressed by reason of its greater potential severity. Some of these have already been mentioned, particularly those related to the circulatory system. A warning was issued against the possible onset of toxaemic nephritis. Fairley and Boyd described renal failure of a kind similar to that found in the "crush syndrome", then not uncommon as the result of bombing raids in Britain. Fortunately this occurred only in the severest infections, and was seldom seen. Andrew investigated the renal function in dysentery of average intensity in a series in New Guinea, but beyond a few instances in which the blood urea content was increased up to 60-70 milligrammes per cent and a few red cells were found in the urine, no significant changes were found. A certain degree of dehydration

was not uncommon; it was particularly evident with the combination of the climatic stresses of heat and high humidity and severe operational conditions. With seriously acute dysentery dehydration could be and sometimes was a dangerous factor. Arthritis has been noted as frequent in some epidemics; in the Australian forces its incidence has been low, though Shiga dysentery has been followed by troublesome polyarthritis. Bonnin and Kay described a small series in detail in which the joint affection was characteristically monarticular. In two instances trauma was thought to have some influence in determining the onset. Only three out of five patients showed any abnormality on sigmoidoscopy, but it is interesting that dysentery bacilli were cultured from the stool of every patient. In several patients the arthritis proved persistent and troublesome, but there was no certainty that an attack of dysentery was alone directly responsible for this. In Tavoy a number of men had acute arthritis affecting the knee as a complication, some had conjunctivitis. All recovered, and no similar series was observed in other camps. In 1942 attention was drawn to a syndrome in which a non-specific urethritis and also arthritis existed in association with a mild Shiga infection. This condition will be discussed in a later section dealing with Reiter's syndrome. Conjunctivitis was sometimes seen, either independently or rarely with a co-existing iritis or iridocyclitis. A few observers attributed conjunctivitis to a toxic action of sulphaguanidine, but this complication was seen in patients with dysentery in Palestine before the drug was used. It is possible that apparently toxic actions of the drug have been due to its action as a provocative agent on the infecting bacteria. Parotitis was rarely seen as a complication of dysentery; it was sometimes slow in resolution.

Chronic dysentery was an important sequel during the 1914-1918 war, but its incidence has been rare in the Australian forces. An exception must be made of the men in Japanese prison camps, where both bacillary and amoebic dysentery were common, with limited means of diagnosis available in many centres, and still more limited facilities for treatment. After the first year in Palestine a few men were returned to Australia with a condition suggestive of chronic dysentery, but with the introduction of sulphaguanidine with the increasing use of sigmoidoscopy and a more rigid standard of cure, residual trouble became rare. In fact, subsequent experience has shown that the commonest causes of after-symptoms have been an acquired conditioned colonic reflex, which is a visceral neurosis, or unsuspected amoebic infection. It seems safe to predict that ulcerative colitis will be a very rare sequel of dysentery. In true chronic dysentery it is usual to find hyperaemia of the mucosa of the colon, or actual ulceration. The more thorough the treatment of dysentery, the rarer are its complications.

In Japanese prison camps, where men were concentrated in large numbers, it was virtually impossible to secure suitable diet or conditions of rest for men with dysentery. In working camps the lamentable conditions made it hard to determine what degrees of pathological states seen before and after death were due to infection and what to malnutrition. Moreover,

amoebic infections were responsible there for much chronic colonic disease. In Changi gaol area a special study of chronic dysentery was carried out at the combined Australian hospital, where a nutritional ward was set apart for these patients, many of whom were seriously ill. An attempt was made to secure a better diet for them, and such treatment as was available was given and controlled by sigmoidoscopic and pathological examinations. Hyperaemic mucosa and ulceration were commonly seen in the colon. Intercurrent diseases complicated the picture, particularly deficiency states; and B_1 vitamin was given as a routine to all. Malnutrition and anaemia were present in over 20 per cent. For 21 patients admitted in the first month of these arrangements the average duration of stay was 84 days, in one case as high as 120 days. Sulphapyridine and sulphaguanidine were available on occasion and even in very limited quantities were found of value. In one series it was found possible to maintain a number of men with chronic dysentery on a bland diet of 2,800 Calories for six weeks. Substantial improvement was noted.

EPIDEMIOLOGY

Observations on the epidemiology of dysentery furnished interesting and important results. No new ground was broken, but great impetus was given to the problem of the carrier, by the use of more accurate techniques and more selective culture media. Knowledge has also been consolidated concerning the antigenic structure of some of the bacterial types. By these means outbreaks of dysentery have been elucidated and suppression facilitated.

The risks of outbreaks of dysentery are increased in closely aggregated communities. Localised epidemics continued to occur in all Services at intervals. These were more evident in the army than in the navy or the air force, not merely because of greater numbers but in part at least because of the larger groups of concentrated population. For example in the Darwin area in the summer of 1943 there were repeated outbreaks of bacillary dysentery in the neighbourhood, but while these reached epidemic proportions among army personnel, they were only sporadic among the navy. In the latter the actual source of attacks was difficult to trace. It is of interest that in the earlier days of 1941, when consciousness of dysentery as an endemic disease in Australia was not so keen, this prevalent disorder in the Darwin area was passed over as "summer diarrhoea" and attributed by local authorities to fruit. Later, a localised outbreak in mess decks of naval establishments proved to be due to Flexner type IV. Again referring to concentration of population, naval ships have not on the whole found dysentery as troublesome at sea as in shore establishments. In ships extraneous sources of infection were fewer, flies were practically absent, water was easily controlled, and sanitation was good.

In the Middle East transmission by flies and by food infected by fingers were recognised as the commonest means of spread. Preventive measures were centred on the adequate disposal of infective material and the

exclusion therefrom of flies. Intensive training of all ranks was carried out, with the use of visual methods with specially constructed models, and also actual work in the field. In Palestine and Egypt warnings were issued from the beginning of the risks of eating unauthorised food, such as fruit and vegetables grown and marketed after the non-hygienic habits of the local inhabitants. These conditions also made difficult the control of fly breeding, especially in the early and later parts of the hot season. Though dysentery was under reasonable control in the Middle East, its inroads on the forces were considerable. In the early stages of the first Western Desert campaign the cold weather and the nature of the stony sandy desert discouraged flies to a good extent. The desert fly, *Musca sorbens,* was plentiful in parts, but despite its bad habits and the difficulties in maintaining strict hygiene in a mobile scattered force, the incidence of dysentery was not serious. When Bardia and Tobruk fell the primitive conditions and overcrowding in the prisoners' cages were so bad that only prodigious effort and constant policing prevented a complete hygienic breakdown. During the siege of Tobruk also conditions were all against the hygiene officers and complete changes in methods of sanitation had to be made in parts of the area, but control was established. Here it is possible that water caused dysentery in some cases: one outbreak at least was thought to be due to men collecting good drinking water (brought by the Italians previously from Italy) in dirty bottles. In 1942, before the battle of El Alamein, trouble occurred in the desert owing to timber shortage, which caused some units to use shallow trench latrines, thereby increasing the fly risk. Strict burning of refuse and control of fly breeding and the provision of fly-proof fittings helped to bring the outbreak under control. Dysentery became more prevalent again after the battle, when the 9th Division moved into former enemy positions.

On the Australian mainland dysentery also occurred in numbers of outbreaks in widely separated areas. In the military camps from time to time diarrhoea occurred, especially during the summer. Much of this was of unidentified type, but dysentery was proved to occur in a number of areas, though of a mild variety. The problem here not only concerned the institution of good sanitation and control of fly breeding, but also the difficulties attendant on troop movements, often over great distances. In 1942 dysentery was endemic along the north-south road to the Northern Territory, and at one period every convoy reaching Larrimah had men suffering from dysentery. Washing and sanitary facilities were scanty on this route, and the men in transit, some 22,000 per year, were difficult to control. At Daly Waters in 1942 the R.A.A.F. had very poor accommodation, and lacked staff for general duties, most of their energies being absorbed on operational sorties. Hygiene was correspondingly poor and dysentery broke out. Fortunately the medical officers secured suitable local quarters for the care of the sick, helped greatly by nurses who had been evacuated from Darwin. The question of supplying adequate labour for hygiene purposes recurred many times during the war, and was not always simple of solution. Another example of this was seen in the contrast between two

R.A.A.F. squadrons in Moresby in 1942. One had a good camp with well organised sanitation and suffered no diarrhoea. The other had a breakdown in camp hygiene, largely owing to lack of labour for this essential work. There was so much diarrhoeal disease that on medical advice the camp was abandoned and a new site selected. Adequate and well enforced hygiene prevented further trouble. Near Darwin diarrhoea was mildly endemic, and here the civil standard of hygiene had been low. Tighter control and improved methods and appliances, such as the incinerating latrine, brought about a better state of affairs.

Base areas were by no means immune from dysentery. In 1941-1942 dysentery gave considerable trouble in Port Moresby. About a thousand cases occurred in the Murray Barracks, owing to bad sanitation and the prevalence of flies. Eventually stringent criticism by the hygiene officer of the I Australian Corps resulted in the detachment of fifty men for the essential labour, after which matters improved. Murray Barracks, like many concentration and staging areas, continued to act as a focal source of infection, from which men carried and spread the disease elsewhere. Base and staging areas were frequently troublesome in this regard, owing to the slackening of discipline and hygiene characteristic of transient populations. In Alice Springs also dysentery was troublesome for a time. The civilian standards of hygiene were not always satisfactory, but matters were improved when the area came under military control. It is of interest that the common dysenteric types here were Flexner type VI and Boyd IV (P274).

Though flies played an important part in the incidence of dysentery in most places, they could not always be incriminated as the prevalent varieties in some areas were not carriers of infections of this kind. This question was raised in an area of Southern Queensland from Warwick to the border, where a considerable outbreak occurred. The bush fly, *Musca vetustissima,* was plentiful, but it did not frequent buildings nor breed or feed in excreta, and therefore was probably not a significant factor. Nevertheless, it was wise to regard all flies with hostility. During the later phases of the island campaigns the influence of fly destruction in lowering the dysentery rate was well illustrated. The R.A.A.F. observed many outbreaks of dysentery within a few days of beach landings. But when aircraft sprayed the areas with DDT to kill mosquitoes, flies were killed as well, up to an estimated total of 90 to 95 per cent, and thereafter dysentery disappeared. Aften seven to ten days insects came in from other areas, and further measures were necessary.

During October-December 1943 in the 1st Australian Armoured Brigade in Western Australia, an outbreak occurred in which the Sonne type predominated. At a dysentery survey centre 49 cases and 58 carriers were investigated. A carrier rate rising to 20 per cent was found and it was estimated that 5 per cent of all personnel in the formation were infected by Sonne organisms. In one battalion in Northern Territory up to 10 per cent of those examined were found to be carriers. Such findings as these were unusual. More typical was the result of investigation of an

outbreak in the 16th Field Regiment in Western Australia. Of 650 men examined, eleven were found to be dysentery carriers: nearly all of these admitted to recent or persistent attacks of diarrhoea. On numbers of other occasions carriers have been found among men engaged in handling food for affected units.

Experience has shown that in trying to suppress an epidemic the local sanitary measures, the water and the control of fly breeding must be strictly scrutinised. Failing arrest of the outbreak, the next step should be to investigate all handlers of food. The methods used were several. The most exact way was found that of taking rectal swabbings of each man; these were cultured on a selective medium, and the results correlated with the histories of the individuals. A course of sulphaguanidine was then given to infected persons who were subjected to further checks before being returned to duty. This method was not always possible. A cruder though practical plan was to collect a labelled sample of faeces from every man in an empty jam tin. These were then cultured direct, or a preliminary sorting made in which those specimens were picked out for culture which contained blood and mucus. It was found that the proportion of positive cultures was much higher from stools containing mucus, and even the segregation and treatment of men found to be passing mucus has been successful in stemming an outbreak. Andrew found in Milne Bay that of 62 men from two companies affected by dysentery seven had fluid stools with or without mucus. In every case recent clinical diarrhoea was admitted by these men, in one instance reluctantly, and their removal checked the spread of the disease; one of them was a cook. An explosive outbreak occurred in the R.A.A.F. at Nadzab in 1943. Sixty-three men were admitted to hospital in one day, and many others followed during following weeks till the cause was found in the general hygiene, particularly in the cookhouse, where there were carriers. Such examples could be multiplied. This method of control was the only one possible in the area at the time owing to the absence of laboratory facilities. In connection with the reluctance of men to report sick with diarrhoeal diseases the practice may be mentioned which was found useful in controlling an outbreak of dysentery in Changi gaol after the arrival of a party from Java. A "tally clerk" was appointed to prevent evasion, and this method together with the prohibition of promiscuous use of eating utensils checked the epidemic.

The obvious importance of local circumstances has been stressed already. The significance of such factors in turning endemic into epidemic disease was again and again illustrated in prisoners of the Japanese. Into Changi prison camp poured a crowd of tired, depressed men. As many as 1,000 were herded into quarters intended for 120. Bombing had destroyed the sanitary system, house flies infested the whole area which was very dirty. The exhausted men, fed on insufficient diet, constructed an insufficient number of shallow and inadequate latrines. Within a week dysentery appeared in the area and spread rapidly. The same and worse occurred repeatedly in working camps. Human carriers were common here also. Even in 1944 the proportion of dysentery carriers in Changi

was estimated at 15 per cent. Amongst other means of spreading infection water was probably important in some of the worse prison camps, where boiling alone could ensure the safety of drinking water.

In this regard water was never a factor of great importance in the Middle East or in Australia, but in New Guinea it was of definite significance. Despite the rapid flow of the streams and its clear and sparkling appearance, running water was frequently contaminated by the insanitary habits of the natives. Even at a base like Moresby great care was necessary in chlorination of the river water. During the Owen Stanley campaign a temporary hospital for infectious diseases was placed on the bank of the Laloki River, and here were treated large numbers of men with dysentery. In one localised outbreak in the upper Moresby area an organism culturally of Flexner type was isolated from a water tank, though it could not be identified at the time. The history suggested water as the cause, and after efficient chlorination of the water, the outbreak ceased. Water was almost certainly a factor in the Owen Stanley outbreak also, described later. It was also found necessary to warn the navy that water for ships obtaining supplies at Port Moresby was polluted and unsafe. Sterilisation in bulk was not possible, and ships officers were informed of the need to chlorinate water from the Bomana pumping station, derived from the Laloki River. Qualified ships' water parties were made available from the engineering services of the army if required for this purpose.

In areas other than New Guinea similar risks sometimes arose. In No. 80 and No. 82 Wing R.A.A.F. at Morotai diarrhoea was prevalent, some 10 per cent of cases being proven dysentery The main water point for the units had previously been satisfactory, containing less than 100 bacterial colonies per cubic centimetre, and no coliform organisms. It was found after heavy rains to contain 2,000 colonies per cubic centimetre and many coliform types. After the installation of a chlorine injector the incidence of diarrhoea fell. In Tarakan also in an airfield construction unit which came ashore early most of the men had diarrhoea; it was thought that breakdowns in the chlorination of underground sources of water were responsible.

Outbreaks in New Guinea were often difficult to control owing to the difficult nature of the country and the military operations. The uninstructed native population added to the problem, as the disease was endemic among them, and indeed caused occasional deaths. An outbreak of dysentery occurred in a nurses' compound following the introduction of a native working party. It ceased on the removal of the natives. Special attachments of officers to deal with regional problems of hygiene were necessary at times, as in the Ramu Valley. The introduction of a change in the hygiene organisation brought improvements too, when the field hygiene sections as such were disbanded and instead hygiene medical officers were attached to all formation headquarters and trained personnel placed with every unit. This alignment of hygiene with the commands, combined with improvement in the methods of implementing policy, proved most successful.

Staging camps were sometimes found to be foci of dysentery. At Morotai King and French reported an outbreak due to the Schmitz organism. This island staging area was an assembly point for a division. Over fifty cases of Schmitz dysentery occurred there, most of them being of mild or moderate severity. Rigorous application of hygienic discipline abated and finally stopped the epidemic.

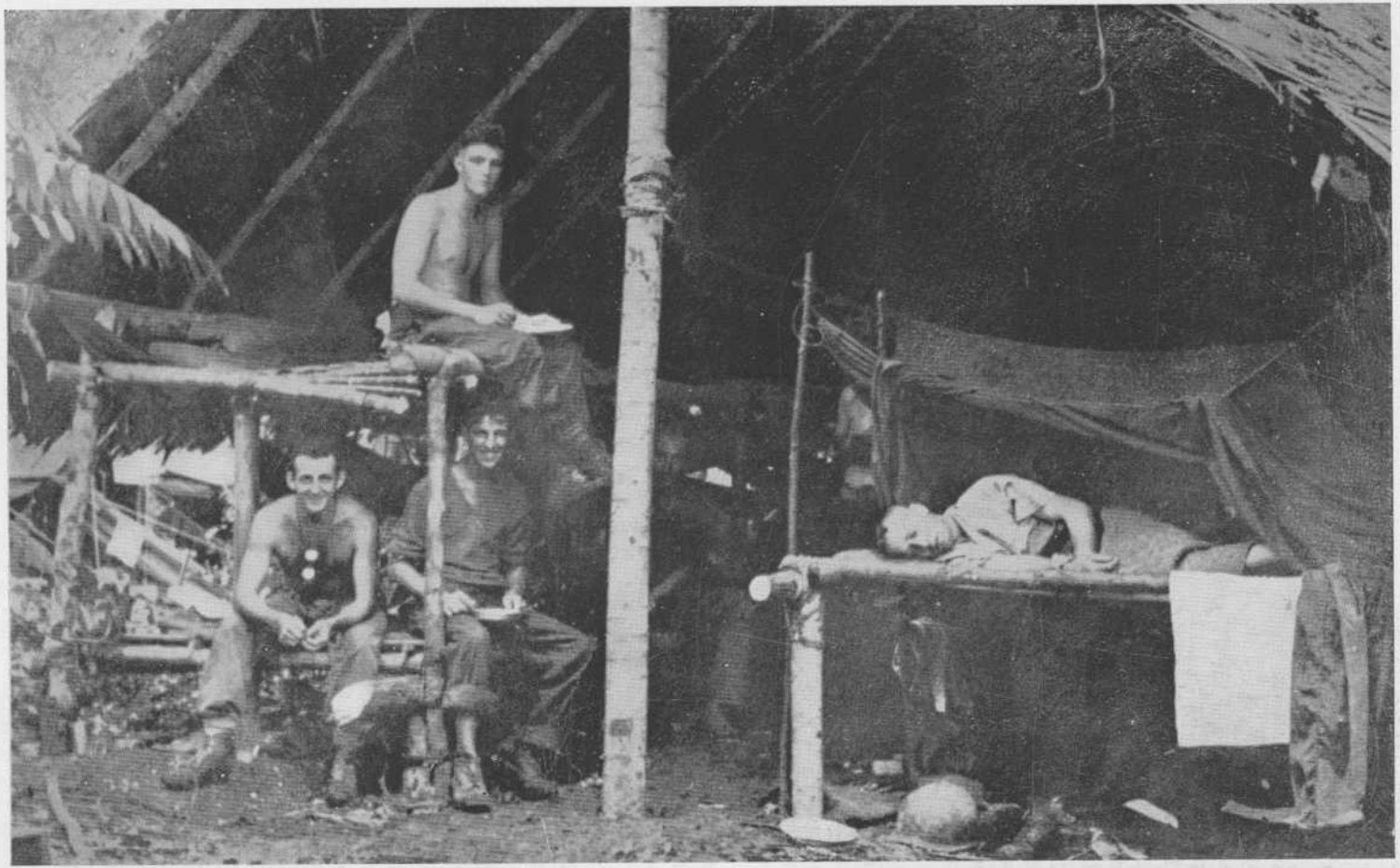
During the Owen Stanley campaign an epidemic broke out which threatened the whole Australian force engaged. Conditions were exacting in the extreme. The Japanese had recently retired from the area, and had left ample evidence of the fouling of the track by infected material. Among the sick those able to walk had to return to hospital along this precipitous path, and their personal hygiene was, in their miserable state, of a low order. Communal handling of food among groups of men no doubt favoured direct infection. Owing to the constant wet and the cold at night, flies were virtually absent. It is more than probable that the lack of sanitary accommodation on this route resulted in contamination of water supplies also. Sterilisation of drinking water depended on the individual and this, never very reliable, broke down when men were sick. Moreover, the outfits for water bottle chlorination were found to be ineffective under prevailing conditions. These defects were remedied later. Most of these infections were of the Flexner type, the average proportion was fifteen Flexner to one Schmitz. Fortunately there was no epidemic of Shiga dysentery, which would have been a disaster. The medical and military positions here were full of hazard: over 2,000 men with dysentery were admitted to medical holding units and disease was whittling away the force. The medical solution was sulphaguanidine. The entire supply was withdrawn from the mainland and flown to New Guinea, where it was supplied to all forward posts, and dropped by air with supplies. All men with diarrhoea were treated with sulphaguanidine and repeat doses administered at conveniently spaced posts as they went back over the trail. The epidemic was rapidly checked, and soon it was impossible to isolate dysentery organisms from the men reaching hospital. The effect of the drug was probably not only to arrest the clinical disease but also to render harmless the abundant faecal material along the track. At Sanananda and later at Lae, Shiga dysentery appeared. There seems no doubt that it had been rife among the Japanese who, according to information gained from prisoners, regarded dysentery as part of the almost universal malarial attacks. This was not in accordance with Australian views or experience, for, while abdominal types of malignant malaria undoubtedly occurred, by far the greater number of attacks of diarrhoea with blood and mucus seen in men with malaria were due to coincident dysentery.

At one time in 1944 men were badly wanted in forward areas, and diarrhoea and dysentery were prevalent. As a field measure a short course of sulphaguanidine was given as a routine at regimental aid posts to all men with diarrhoea, a total of 76 grammes being given in five days. Only men with severe or persistent forms were evacuated. This procedure was found very effective and free from any harmful effects.



(F. H. Taylor)

Possible vectors of dysentery: flies outside cookhouse door.



(Australian War Memorial)

New Guinea—Finschhafen: native huts for patients with dysentery.
(Note no fly screens, etc.)

OTHER PREVENTIVE MEASURES

It will be seen that epidemiological experience with dysentery during this war covered all aspects of its propagation, and that its control called for application of all advances in clinical and bacteriological features of this disease. Even therapeutic measures were applied in the preventive sphere. Vaccines to immunise against dysentery were not thought by the advisers of the Australian medical services to be of sufficient value to warrant their use. An attempt was made, however, in Changi, soon after the fall of Singapore to immunise the force against dysentery by this means. Major Burnside of the 2nd Mobile Bacteriological Laboratory prepared a vaccine which was used with inconclusive results. The Japanese also issued a dysentery vaccine which was given to all in the area; similar inoculation was used in other prison camps at the instance of the Japanese medical service. There is no evidence that any degree of protection was conferred by this method.

Major H. H. Eddey on the other hand thought that at Kuching in 1943 there was evidence that some immunity was produced by a vaccine with which the men of "E" force had been inoculated before they left Singapore and again later at Sandakan. Both here and at Kuching the incidence of dysentery remained low in spite of extremely primitive conditions. By contrast in Kuching in 1945 when bodily resistance was at its lowest and was not reinforced by inoculation, a severe outbreak occurred.

In spite of the difficult island areas in which the later stages of the Pacific war were fought, there was a consistent lowering in hospital admission rates for dysentery. The disease itself took on a milder character and the death rate, always low, became negligible.

The nature of bacillary dysentery, its high degree of infectivity, and the above diagnostic measures necessary for its control determine the organisation of the special wards evolved to meet these needs. An official design was adopted for a dysentery ward based on the experiences of the earlier A.I.F. hospitals in the Middle East. It is interesting that even in 1943 an inadequate latrine design was incorporated in the plan, owing, so it appeared, to the impression that most of the patients at any given time were "pan patients". This was based on memories of the 1914-1918 war, not on the totally altered picture of the dysentery war since the introduction of sulphaguanidine. Further details of this evolution belong rather to the operational history of the medical services and are dealt with elsewhere. It may be said here that dysentery wards could easily be made safe and efficient by establishing annexes in which all excreta were dealt with, and by the use of fly wire and all anti-fly measures. Adequate methods of destroying infective material, preferably by incineration were adopted, and bed pans were sterilised by boiling. Even such devices as covering door handles and other objects which might be contaminated with lysol-soaked cloth were found of value, especially as constant cautionary reminders. Early in 1940 fly wire was scarce in the Middle East and it was not possible to protect entire dysentery wards in this way, but the use of

individual mosquito nets and insistence on strict discipline kept the wards safe.

TREATMENT

In the treatment of dysentery complete bed rest was insisted on wherever possible as an important factor in speeding recovery. Diet was at first entirely fluid, sufficient fruit drinks or other form of diluted monosaccharides being taken to secure a positive fluid balance. A less dogmatic insistence on preliminary starvation was noticeable as time went on. Among undernourished men such as those in the Japanese prison camps it was found advisable to try to avoid nutritional losses from the beginning. Even in non-infective diarrhoea this was so. Surgeon Lieut-Commander S. E. L. Stening reported many cases of fermentative diarrhoea among naval and other service personnel in Japanese camps due to the eating of indigestible material like leaves and berries by half-starved men. He found it necessary to ensure that all of each man's meagre ration of protein should be consumed, in the hope that some would be absorbed. In men severely ill the keeping of a fluid balance chart was desirable; it was useful *inter alia* in securing adequate administration of fluids. Occasionally parenteral administration of fluid was needed, but usually vomiting was not so troublesome as to preclude the taking of enough fluid by mouth. Semi-solid food was given as soon as the clinical state permitted, and fats and roughage were withheld until convalescence was begun. After the introduction of sulphaguanidine the rapid progress of patients on this drug caused some revision of dietary ideas, and more substantial increases were allowed earlier than previously. Milk was usually found to be tolerated well in reasonable quantities. Pain was a symptom which needed relief in most severe infections. The conventional tincture of opium in 15 to 20 drop doses was given for this in some hospitals, but a hypodermic dose of morphine for a couple of nights, or even during the day is incomparably more effective. It has been found too to be useful therapeutically where the urgency of the diarrhoea is great: it seems reasonable to believe that a slowing of peristalsis gives greater opportunity for a drug such as sulphaguanidine to act locally.

The greatest advance in the treatment of bacillary dysentery was the introduction of sulphaguanidine. While other sulphonamides were very effective, the safety of sulphaguanidine and its freedom from trouble or risk of renal complications, especially in hot humid climates, enhanced its therapeutic value. Through the efforts of Fairley a supply was obtained for trial in Middle East, and it was then and has remained first choice with the Australian forces. Its introduction and use by the A.I.F. for the first time by any army are described in another volume. In 1941 in the Middle East, Flexner types II and VI were the commonest bacterial groups, the next in frequency being the Shiga. Fairley and Boyd carefully checked the use of the drug by sigmoidoscopy and culture, and on seeing chronic ulcerative lesions heal under their eyes had no doubt that it was a specific. Its only drawbacks were its bulk and its expense. By compensation, the use of sulphaguanidine removed the need for much of the previous

long and rigid dieting, thus relieving pressure on wards and kitchens. On the other hand its low degree of absorption from the bowel meant low toxicity, and though crystals were passed in the urine they were soft and harmless. No renal troubles ever occurred, and even in the tropics there was no risk of dehydration causing dangerous renal concentration. Toxic effects were observed, but they were not of importance. Some of those described by some writers have not been seen by others. For instance a necrotic effect on the mucosa of the bowel ascribed to the drug must surely have been due to a manifestation of the disease. Australian physicians have studied carefully the question of toxicity. A rash, erythematous or macular, sometimes morbilliform in type, was seen in a small proportion of cases. It appeared most commonly after four or five days, and was sometimes accompanied by enlargement of the lymphatic glands. Headache and fever were also noted, with some digestive disturbances and anorexia. Blood disturbances were virtually absent: granulopenia was recorded in one instance. The percentage frequency of toxic manifestations varied from 2 to 4 per cent in some series; in others it was even lower. Constipation was found to be troublesome by some; this seemed rather more frequent when the frequency of the stools was low, as in carriers. The free use of the drug in controlled dosage by carriers or by men with mild symptoms in forward areas was found to be without any risk. In New Guinea it was found that the toxic manifestations of this drug observed after its use in some 20,000 persons were negligible. It was not used in every instance of bacillary dysentery, for example, in mild attacks in base areas which resolved with correct diet and rest.

Following a conference of physicians in Cairo in 1943 at which the desirability of more controlled observations was discussed, parallel series treated with and without the drug were compared. West treated parallel groups with sulphaguanidine and the older conventional sodium sulphate. He found that with sulphaguanidine stools became normal in an average period of 7 days, and patients left hospital well after 12 days, the sigmoidoscopic appearance of the bowel being then normal. In the control series the comparable figures were 15 and 21 days. Gard also studied a series of Shiga infections in 1942-1943 in New Guinea. The average total dosage was 152 grammes and stools became normal after 11.5 days. Results were uniformly satisfactory, though the treacherous nature of this type of dysentery was illustrated by the fact that mucosal ulcers were seen in 5 patients who had apparently recovered. Bruce Hall in 1944 in New Guinea found that after a short five day course totalling 76 grammes given to men with mild attacks, some evidences of persisting infection were seen on the eighth day, though cultures were then negative in practically every case. After an eight day course of 112 grammes examination on the eleventh and twelfth days discovered very few incompletely healed ulcers, and in only one instance out of fifty was the dysentery bacillus grown on culture. These observations were carried out on men under conditions of operational stress in which military expediency dictated the measures adopted. Cornish and Morris also produced evidence of more

rapid and complete resolution of dysentery with sulphaguanidine than with other methods. Their observations were of particular interest, as the men treated had come from the Owen Stanley Ranges, usually arrived in an exhausted state, and were suffering from varying degrees of nutritional deficiency. Undoubted instances of thiamin deficiency were observed in men who had been in action on the ranges for some six weeks, though this period is less than that usually required to produce clinical thiamin deficiency. A number of these men complained of discomfort and flatulence after the fourth or fifth day; it was suggested that this was possibly due to a change in the bacterial flora of the bowel by the action of the drug. A trial was made of half doses (4 grammes initial dose followed by 2 grammes four hourly) and more satisfactory results were obtained. Further investigation was not possible under existing conditions at the time. S. E. L. Stening, after observing the effects of diarrhoea and other infections in men with beriberi, thought that sulphonamides tended to exacerbate the oedema, and suggested that this might be associated with the alterations in bacterial flora in the intestine due to the drug. It is possible, in view of experimental and other observations made elsewhere since 1943, that the effects of sulphaguanidine on persons in a state of disordered nutrition might be different from those otherwise in good health. It is known that the administration of drugs of this type can cause altered demand for some accessory food substances and, in addition, altered conditions of absorption and output. In general, however, the dosage used has approximated closely to that laid down in the Middle East, an initial dose of 0.1 gramme per kilo weight, with a four hourly maintenance dose of half this amount until the stools fall to five a day, when the dose is given every eight hours until stools are normal. A period of fourteen days was not exceeded.

While these observations were proceeding the Malayan forces in captivity were confirming their results under very different conditions. Supplies of sulphaguanidine were limited to small quantities brought over from the Middle East and others later obtained from the American Red Cross. Sulphapyridine was also available at times, through the same source, or hidden stocks, and in small amounts through the Japanese. The latter drug was found to be very effective. In 1943 a closely controlled series was observed at Changi, and even with a total dosage of less than 10 grammes given in one or two days, its specific action brought about quick improvement and more rapid recovery. Nausea and vomiting were present in 30 per cent, but were mild. In chronic dysentery its value was also established. Sulphanilamide was also tried, but without result. On the hard 300 kilometre march between Nieke and Bampong sulphapyridine helped to mitigate the sufferings of men with dysentery in "F" Force and in Tamarkan, too, enough of the drug was obtained secretly to enable its great value to be appreciated. Sulphaguanidine was available in small amounts in 1943, most of it having been brought from the Middle East and at Nakom Paton hospital area later was found very useful. It was

obtained through the Red Cross in 1944 and even in less than full doses was found to have a specific action in dysentery.

Cases of resistance to sulphaguanidine were reported by a number of observers, but these were exceptional. Carriers sometimes required a repeated course before they were free from infection. Experienced observers doubted if the percentage of attacks of dysentery resistant to sulphaguanidine ever exceeded 0.5 in any series.

Thus on all fronts the early observations of Fairley and Boyd have been amply confirmed. Other authorities have produced similar proof: for instance Bulmer and Priest abandoned purgative treatment in 1941 and found with an average dose of 100 grammes of sulphaguanidine, the maximum being 350 grammes, a quicker and more complete recovery took place, toxic symptoms being rare.

Antiserum was not used with the exception of a special endotoxic serum prepared by Burroughs Wellcome from Shiga strains. The early A.I.F. hospitals had stocks of polyvalent dysenteric serum, but the unknown unitage and the doubtful propriety of giving unconcentrated alien serum to sick men, together with unfavourable experiences in the use of these preparations, led to their non-use. The refined Shiga serum, specially made available to the Middle East forces, contained 20,000 international units to 1 c.cm. and was given intravenously in doses of 5 to 10 c.cm. It was used in severe Shiga infections in the hope of neutralising the Shiga endotoxin believed to be responsible for the highly toxic effects of this type, but the results were not striking. This concentrated serum was also tried in the treatment of a few complications such as arthritis, but without definite result. There was no evidence of it playing an important role in treatment, though no controlled observations were possible.

SUMMARY

The clinical and epidemiological story of dysentery emphasises that its control was never a static achievement. Hygienic control was on the whole satisfactorily achieved, but the disease was always ready to break out whenever preventive discipline slackened. It has been demonstrated that invalidity, sequels and death rate can be substantially lowered under favourable conditions almost to vanishing point. Therapeutic control was established; perhaps in latter years this relative clinical mastery over the disease tended to obscure its still great military importance. During the war years exact knowledge of the disease has been diffused among a very large number of service medical officers, and also, it is hoped, among non-medical men and women. The most important advances have been the use of the appropriate sulphonamides, and the firm establishment of sigmoidoscopy as a routine diagnostic measure and an essential element in the standard of cure. This knowledge, if applied with the same zeal, should be an asset to the civil community.

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CHAPTER 2

AMOEBIASIS

AMOEBIC infections were not numerically of great signficance in the Australian armed forces during the war, but by reason of the diagnostic and therapeutic problems involved, and the degree of disability they caused, they were important. The number of days of treatment needed in hospital in each case ranged from 40 to 60 or more, and relapses increased the total time necessary for recovery. There were 783 cases of amoebiasis recorded in the A.M.F. during the war, excluding the 8th Division. In some periods the numbers rose to a proportion of 10 per cent of the figures for bacillary dysentery, though the latter were certainly greater than hospital figures indicate.

The figures and rates were as follows:

	Year	Number	Rate per 1,000
Middle East . . .	1940	8	0.562
	1941	135	1.77
	1942	2	0.248
Australia . . .	1943	207	0.514
	1944	161	0.436
	1945	79	0.308
	1946	45	0.30
New Guinea . .	1943	34	0.436
	1944	54	0.773
	1945	13	0.319
N.E.I. and S.W.P.A. other than N.G. .	Apr.-Dec. 1945	45	1.103

It must be understood that the places of notification are not necessarily those of origin of the infection, owing to the periods of latency and the occurrence of relapses.

Amoebiasis has occasionally appeared in localised limited outbreaks in Australia, and cyst carriers have been recognised in the few surveys that have been made, just as in most countries in the world. During the war it was necessary to be on the watch for amoebic infections because of the actual or potential risk to members of the armed forces and the civil community. Amoebiasis was known to be endemic in the action zones of the Middle East, and in New Guinea and other Pacific islands, and had to be looked for not only during active service, but also after the return of men to civil life. Prisoners of war, both in Australia and overseas, were also potential sufferers from, and carriers of the infection.

For the purposes of systematic description the lesions caused by the *Entamoeba histolytica* may be divided into colonic, hepatic and pulmonary types. In interpretation of the varied clinical signs awareness is necessary of the pathological features of the disease.

CLINICAL FEATURES

(1) DYSENTERIC

The clinical types of amoebiasis seen were chiefly those associated with subacute or chronic abdominal symptoms. Acute amoebic dysentery was rarely seen except in the Japanese prison and working camps, where terrible conditions often predisposed to severe and uncontrolled infections. In these the necrotic features of the pathological lesions were sometimes exceptionally severe, causing massive sloughing associated with haemorrhage. Under the controlled conditions even of active warfare on other fronts such acute manifestations of the destructive effect of *Entamoeba histolytica* were not seen. As a rule toxaemia was of moderate grade only in the usual subacute form of the infection. The characteristic stools, containing necrotic material, blood and pus cells, were sometimes found immediately, suggestive of destructive lesions of the colon; but such declared types were not very common. An attack of bacillary dysentery sometimes awakened a latent amoebiasis and this caused considerable confusion unless the latter was thought of; an amoebic infection could steal on under cover of a bacterial diarrhoea. In the Middle East in the later periods men were seen with an established amoebiasis who had been treated earlier for "clinical dysentery". The subacute type tended to merge into the chronic; indeed chronicity is a feature of amoebic infections. This fact, taken with the moderate grade of toxaemia usually observed, is evidence of the possession of some degree of immunity by the human subject. This will be referred to again later.

Temperature was usually raised at some stage. A polymorph leucocytosis sometimes reaching 15,000 or 20,000 cells or even more was a common feature, helpful in diagnosis. Eosinophile counts gave no useful information, for eosinophilia is not a feature of amoebiasis. When eosinophilia was observed another cause was practically always found. Abdominal disturbance of some kind was invariable. Even in the hepatic metastases some history of looseness of the bowels, dyspepsia or merely discomfort was usually obtained. In chronic states the presence of persistent discomfort was found suggestive. Pain was usually present to some degree all over the abdomen; in the types most commonly seen it was localised in the right lower quadrant, and often also in the right loin. Proctitis was occasionally a troublesome symptom: its existence was even suggestive of amoebic infection. In a few instances the pathological basis of anal fissure proved to be amoebic.

(2) HEPATIC

Amoebiasis cannot be sharply divided into colonic and hepatic types. Hepatitis was diagnosed in numbers of patients who never suffered from liver abscess, and yet abscess has occurred in other patients whose colonic signs and symptoms have been indeterminate, at least without careful enquiry.

Enlargement of the liver was suggestive of an amoebic lesion, but enlargement of the spleen, though stated to be a useful sign, was not found

helpful, since there were so many other causes. In fact, in service experience splenomegaly when associated with amoebic hepatitis was only secondary to hepatomegaly. The enlarged liver was commonly tender, and pain could be elicited by compression of the lower ribs. Jolting in transport over rough roads frequently excited pain, this information being sometimes volunteered by patients in New Guinea. Dyspeptic symptoms were common, although they sometimes drew attention away from the true focus. A combination of dyspepsia with symptoms involving the lower part of the abdomen was suspicious, especially if associated with tenderness of the liver. A long latent period between the presumed time of infection and the onset of relevant symptoms was often misleading, though sometimes actually suggestive. The picture of a febrile disease occurring in an endemic area and mainly characterised by upper abdominal discomfort and tenderness should always suggest the possibility of amoebic hepatitis, though the diagnosis may often be in doubt for a time. Where abscess had formed in the liver the diagnosis was usually readily made, though it might be complicated by the extension of the process to the thorax.

(3) PULMONARY

Involvement of a lung was not very uncommon; it was always found in association with hepatitis and particularly with liver abscess. It seems to have been more often seen in the Middle East than in New Guinea or base areas in Australia. The pulmonary signs were most frequently found at the base of the right lung; they were usually impaired resonance, crepitations, pleural friction, altered breathing or evidence of fluid in the pleural cavity. Occasionally an hepatic abscess became by extension a pulmonary abscess or discharged through the bronchial tree. Affection of a lung could be confusing if the patient was seen when this was the chief presenting symptom. Indeed the provisional diagnosis was frequently incorrect. M. L. Edwards reported a case of amoebic pericarditis successfully treated, though the diagnosis was presumptive on the grounds of physical signs which suggested involvement of the pericardium.

No detailed account of the pathology of amoebiasis need be given here: this information is readily accessible. But it should be stated that experience has shown that amoebiasis is essentially a disease whose successful diagnosis and treatment depend on a ready knowledge of its pathology.

DIAGNOSIS

Diagnostic errors were not rare; even experience could not always avoid them, but certainly minimised them. A thoughtful review of many amoebic infections evokes the reflection that in a great number an earlier diagnosis could have been made on the application of greater insight and persistence. Surgical explorations do not always reveal the true disability. Appendicectomy has been performed a number of times and a substantial lesion in the appendix has not always been found. Coates found that the frequency of appendicitis among 1,500 men in the dysentery block of Nakom Paton

hospital exceeded that of 6,500 other men. The usual finding at operation was a necrotic process without lymph or adhesions. Pulmonary consolidations have been thought to be primary, so too have pleural exudates and intrathoracic abscesses. Secondary infections confused the issue at times: for example *Haemophilus influenzae* was grown from an empyema which was found afterwards to be secondary to an amoebic liver abscess. A diagnosis of neurosis has even been made in cases in which persistent complaint was made without any cause being determined.

Special technical instructions were issued concerning the diagnosis of amoebiasis. Particular stress was laid on the frequent difficulty in recognising the hepatic form, though most of the difficulty disappeared with a thorough knowledge of the disease. The correct pathological outlook was well summarised as follows:

"The first stage in infection of the liver consists of so-called amoebic hepatitis, and here the amoebae have been carried up via the portal vein and distributed through the liver as emboli derived from thrombosed vessels draining submucous ulcers in the large bowel. Enzymes secreted by the amoebae lead to local necrosis of tissues, while the fusion of adjacent foci gradually produces an abscess. Abscess formation is the end result of a progressive infection commencing with intestinal amoebiasis which may or may not have given rise to clinical dysentery."

The importance of amoebic hepatitis as an obscure cause of fever was stressed. A constant awareness of this possibility was found to be one safeguard to error by omission. One frequent source of error lay in the misconception that amoebic hepatitis is a fulminating disorder, it was commonly less spectacular. This was specially necessary having regard to the variability of the intestinal history. Nevertheless, exact information was essential concerning the state of the mucous membrane of the colon and the nature of the cellular contents of the excreta. This could be gained only by the use of the sigmoidoscope and the frequent and repeated microscopic examination of the stools. As with bacillary dysentery, a great forward step was made when sigmoidoscopy became a routine diagnostic procedure. Usually the mucous membrane in amoebic infections was found to look healthy except for the distinctive lesions themselves. These consisted of areas each ringed by a zone of hyperaemia or petechiae, in the centre being a granular surface, yellowish nodules or oval ulcers. The base of the ulcer appeared only after swabbing or gently scraping away inflammatory material and debris; and from this base vegetative forms of *Entamoeba histolytica* could often be demonstrated under the miscroscope. The swab method used for diagnosis of bacillary dysentery was not satisfactory for the discovery of amoebae. The larger granulomatous or ulcerated lesions were not often seen, except in severe infections, for example, in debilitated patients. Such infections were seen in prison camp hospitals such as Chungkai where 20 per cent of the patients with amoebic dysentery died during 1943. Here specific drugs were not supplied by the Japanese, and the amount of emetine available was very small. The lesions in the bowel were frequently not circumscribed, but formed florid inflammatory swellings. Local gangrene ensued, often spreading to cause peritonitis with or without perforation. Severe haemorrhages occurred,

often following the passage of huge foul sloughs. The course and management of these desperate lesions, fortunately not seen under ordinary conditions, formed a special problem, which will be described later.

Microscopic examination of the dejecta is of great value, provided that rash conclusions are not drawn from the failure to find amoebae of the vegetative or cystic type in one or two specimens. Major A. T. H. Marsden, who acquired an immense experience in the recognition of the entamoeba under these conditions, has pointed out that cysts are passed intermittently, and that their detection will depend upon the degree of this intermittency and the actual numbers excreted. Where less than 10,000 cysts a day are passed the detection of chronic dysentery by this means is not practicable except in a small minority. In 1,100 cases he found that six consecutive stools examinations disclosed one or more cysts in about half the infections. His own estimate was that in 20 per cent of cases cysts were found on one examination, 30 per cent on two, and 37 per cent on three. These figures confirm the necessity for the examination of material obtained by sigmoidoscopy. Bruce Hall from an analysis of some hundreds of cases considered that sigmoidoscopy yielded positive diagnostic information in 40 per cent, results confirmatory of history and clinical examination in 20 per cent and no positive help in 40 per cent. Under ordinary conditions the essential feature of amoebic lesions was seen to be a focus, especially in the subacute infections. The microscopic features of the stool, or rather of the cells and other material found in an appropriately selected flake of mucus, were not always distinctive. The exudate was not typically a "bacterial" one, but rather of the "indefinite" type. Red cells were found with considerable constancy and some degenerate tissue cells were commonly seen. Charcot-Leyden crystals have proved to be of some diagnostic value in arousing suspicion. It is unnecessary to repeat here descriptions of the entamoeba in its active trophozoite form or its vegetative cyst. Great care was taken that those upon whom devolved the duty of identifying this protozoon should have sufficient experience, and intensive training was given not only to pathologists but also to clinicians handling the disease. Errors in the recognition of this organism have occurred before by mistaking other protozoa or amoeboid macrophages for amoebae. The rapid movement of the blunt pseudopods, the delicate tracing of the nuclei and the inclusion of red cells should be distinctive. In the microscopic examination of suitably fresh material it was not found essential to use a warmed stage under the conditions usually prevailing in the tropical areas where most of the work was done. The finding of other protozoa or of worms or their ova in the stool gives rise in itself to a suspicion that the entamoeba may also be there. The presence of *Iodamoeba butschlii*, though itself usually considered non-pathogenic, may be a pointer. *Strongyloides* infestation and entamoebic infection have also been known to co-exist in some tropical areas. Despite all endeavours, the microscopic diagnosis could not always be made, and there remained the method of therapeutic trial, of which more will be said later.

DIAGNOSIS OF LIVER ABSCESS

Once the end result of liver abscess had been reached, special regional methods were of value in diagnosis, which depended on demonstration of structural changes rather than of the causal organism. The local signs were all the more convicing when they occurred after a period of remittent fever and sweating with no other obvious causes. Abscess in the right lobe usually gave rise to pain referred to the right shoulder, and to signs of diminished air entry at the base of the right lung. Where the abscess involved the lower portion of the lobe localised tenderness, particularly on movement or pressure, was more common. Owing to this the patient often preferred to lie on the right side. Abscess of the left lobe often caused epigastric signs, which could be confusing. Radiological methods were of value in diagnosis. The signs most commonly found were diminished movement or "splinting" of the right or occasionally the left cupola of the diaphragm, or distortion of a cupola, or increased density of the liver shadow. Signs of consolidation or collapse of a lung or of pleural effusion were also suggestive.

EPIDEMIOLOGY

The investigation and treatment of individual patients was mainly a matter of penetrating investigation and deduction, but the epidemiological problems were often even more obscure. In certain areas the higher incidences were associated with poor hygiene; the experiences of the 8th Division in captivity bore witness to this. An extreme example may be quoted from Thailand: during one year out of 11,347 men admitted to hospital in Chungkai, 1,309 had amoebic dysentery. It was of interest here that the figures for bacillary dysentery were only half those for amoebic. The conditions were of course exceptional. On other fronts no important outbreaks of amoebic dysentery occurred, though rates of incidence varied. Spread of amoebiasis was by the means familiar in other intestinal infections. Where there was a risk of bacillary dysentery amoebic infection might be a concomitant hazard. Water has been recognised as an important carrier of amoebae. Chlorination of water within potable limits would not kill the vegetative forms of *Entamoeba histolytica,* but filtration effectively removed them. The army mollinite filter was estimated to be as adequate for this purpose as some 6 feet of soil. The trophozoites were much more vulnerable, but safe methods of sanitation were essential, though cysts could not survive drying. In parts of New Guinea the sanitary problem of disposal was complicated by the proximity of the water table to the surface of the ground. In the Moresby area at one time some concern was felt about the complete safety of chlorination of the water of the Laloki River, which ran some risk of contamination by the presence of a temporary dysentery hospital on its banks some miles upstream. Insects such as flies could act as vectors, and contaminated food was also a real risk. It was unlikely that food soiled by carriers could maintain an epidemic, but it could initiate an outbreak. The site of origin of an infection was not always easy to determine. A man seen in New Guinea with amoebiasis might have been infected in Syria. Of 50 patients seen in

a hospital in New Guinea 14 were believed to have contracted the infection in the Middle East, 22 in New Guinea, and the remainder had infection of doubtful origin. A definite crop of infections from Syria, for example, was seen after the return of troops to Australia.

In 1943-1944 the incidence of amoebic infections was watched closely in New Guinea. By this time most relapses from infections originally acquired in the Middle East would have declared themselves, and since diagnostic accuracy was then of higher degree, clinical infections seen among troops in New Guinea would presumably have arisen there. Though it was not expected that the numbers would be great, the troops strengths were considerable, ranging from 60,000 to 100,000. As shown in the figures quoted above the rate was not unduly high. The average of amoebic infections among all forms of dysentery in New Guinea over this period was recorded as 3.5 per cent, but at a general hospital in Lae out of 1,400 admissions to the dysentery ward over a period of twelve months the proportion of amoebic infections was 8.7 per cent. Subsequent experience has shown that the figure of 3.5 per cent is unduly low: the higher estimate is probably nearer the truth, even allowing for the known association of bacillary and amoebic dysentery.

The problem of the carriers of amoebic cysts caused earnest thought on several occasions. Its importance depends on the possibility of an outbreak of amoebic dysentery in a community. A survey made by Lancaster (quoted by Andrew) of 1,000 Australian troops over a period of five months is of interest. Of these men 5.5 per cent had cysts of *Entamoeba histolytica* demonstrable in the stools. This figure is within the apparent norm found by surveys in most parts of the world not specially subject to amoebic infections. Dissection of the results showed that the percentages were highest among those who had been exposed to infection in the Middle East, reaching 10 per cent; the figure for those exposed to possible infection in New Guinea alone was 3.7 per cent and in Australia alone 3.2 per cent. Other earlier Australian figures as presented by Heydon suggest a corrected average rate of 8 per cent in Townsville, and another later series in soldiers never out of Australia gave 2 per cent.

A. J. Bearup, J. J. Lawrence and G. A. M. Heydon also surveyed soldiers in the General Details Depot in Sydney from December 1941 to November 1943, to determine what percentage showed evidence of being cyst carriers or of active infection. Multiple examinations were not always possible; the best results were obtained by flotation methods, with the use of zinc sulphate. They only found *Entamoeba histolytica* in 1.3 per cent of 2,365 men who had never been out of Australia. Their series included 210 men who had served outside Australia, but no histolytic amoebae were found among these. The results of these surveys, though variable in their figures, suggest that the cyst carrier rate in Australia does not exceed the usual figures for other parts of the world.

The internment of Italian prisoners of war in Australia brought up the cyst carrier as a problem of public health. In 1941 prisoners were brought to Australia in whom there was good reason for suspecting amoebic

infection. Numbers of such prisoners had suffered from amoebic dysentery in the Middle East, their previous hygiene had been poor and the conditions of the compounds in which they had been confined immediately after surrender had been very bad. Surveys were made and a considerable number were found to be harbouring cysts. At Tatura camp a single examination showed a cyst rate of 6 per cent, a figure consistent with civilian average. At Murchison 161 suspects showed a rate of 11 per cent, whereas others showed only a rate of 5 per cent. At Cowra, in New South Wales, a special sewered compound was established for carriers of amoebic cysts, and here 350 prisoners were kept under very good conditions. After several months re-examination revealed only 122 as persistent carriers, but no clinical affections had occurred among them. At Loveday and other camps a certain number of clinical attacks occurred, but yielded to treatment. At the end of 1941 and early in 1942 examinations were made of Japanese internees at an army mobile bacteriological laboratory, and the Walter and Eliza Hall Research Institute in Melbourne. Only 3 per cent of 228 were found to harbour cysts. It is obvious that such surveys can yield only approximate results, but the figures are sufficiently consistent to be of some value.

The questions raised here were the indications for treatment, if any, and the possibility of risk to the civil community. Excepting where clinical symptoms appeared no treatment was adopted: in any case all anti-amoebic drugs were then so scarce in Australia that it was difficult to secure enough to treat men with overt disease. Under conditions of good nutrition and strict hygiene the proportion of carriers diminished. Later the Cabinet decided to allow numbers of these men to work in rural districts and the question of risk was considered. Though medical opinion was not completely unanimous, the D.G.M.S. of the Army thought that any danger was unsubstantial, and the men worked well and remained in good health and without any known hazard to others. After the end of the war a check of prisoners of war from prison camps in Italy showed that 60 to 70 per cent were passing cysts, but none had any symptoms. Yet the 2/14th Australian General Hospital, sent to Malaya to receive 8th Division prisoners of war, surveyed 1,297 men, including those with clinical diarrhoea, and found only 3 per cent to have cysts. Seventy-three cases of clinical infection, most of them severe, were confirmed at the same time. It must be admitted that unless comparable conditions of investigation exist in such surveys, no statistical conclusions can be drawn.

Under static military conditions instances occurred of infection apparently arising from within. Thus Kay and Johnston reported a series of seven cases of amoebiasis in the Northern Territory: of these men five had never been out of Australia. They presented symptoms of persistent diarrhoea with vague abdominal pain and three came from one unit. A series of fourteen cases was reported from the 2/2nd A.G.H. at Atherton in North Queensland. Most of these were thought to have arisen in the Middle East, but some were probably New Guinea infections. In a few the source was thought to be North Queensland. On the other hand Aus-

tralian experience in Syria indicated that while amoebiasis was a well recognised risk there, it did not appear to be common as local reports suggested. In New Caledonia also it was stated to be common, yet Captain Patrick, with an Independent Company in 1942, reported that it had not been encountered in Australian troops, nor was it found by a special American board of investigation. In Borneo too amoebic dysentery was said to be common, even more common in places than bacillary dysentery. This was contrary to Australian experience at the time, though evidence of the disease was found and confirmed in later observations of men in these campaigns. Here the military conditions, except for brief periods, were relatively favourable and the special measures then possible against fly infestation probably lowered the risk.

It is difficult to reconcile the conflicting aspects of this disease, but the overall experience of the Australian medical services has confirmed that it is a condition apparently widely, though not densely, spread in all communities. It does not readily assume acute epidemic form, but may do so under conditions of privation, and poor nutrition and hygiene. Small outbreaks may occur from time to time, even in families. The answer at present lies in adequate hygiene, thorough treatment of patients, and a high standard of cure.

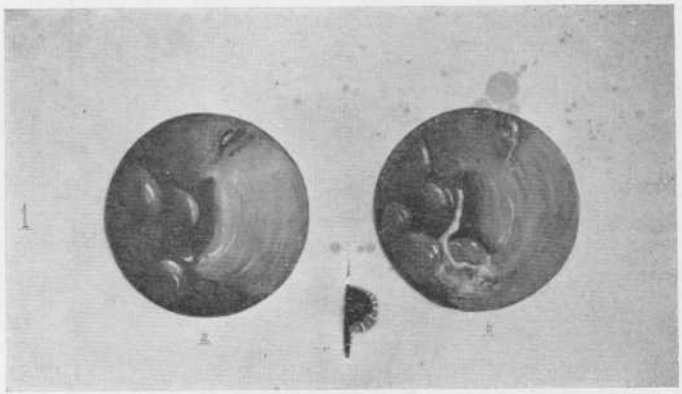
IMMUNITY

Consideration of the epidemiology of the disease must also take into account the degree of immunity established by clinical attacks, as well as such natural resistance as most people seem to possess under ordinary conditions. The apparent harmlessness of cysts in the intestine of healthy people is witness to the existence of some natural barrier to infection, which can be broken down by malnutrition or intercurrent disease, particularly other dysenteric disease. When clinical infection occurs the amoebae may live for periods of years within the body, yet even with specific treatment the disease is notorious for relapsing. In a vast experience in Malaya, Burma and Thailand Australian medical officers were able to demonstrate the gradual acquirement of some degree of immunity once their patients, even though malnourished, had surmounted the initial perils of severe infection. In Nakom Paton 1,346 men out of 1,500 men were found to be carriers of active amoebiasis. A few men suffered from liver abscess; in others massive and florid infections of the colon were present, some requiring surgical drainage. In spite of the lack of specific drugs, numbers of these men eventually recovered, some of them after being desperately ill. At Changi also spontaneous improvement was noted in a number of patients. No fewer than 120 new cases were diagnosed in one period of six months, and though few facilities for treatment existed, some men improved in spite of the handicap of substandard nutrition.

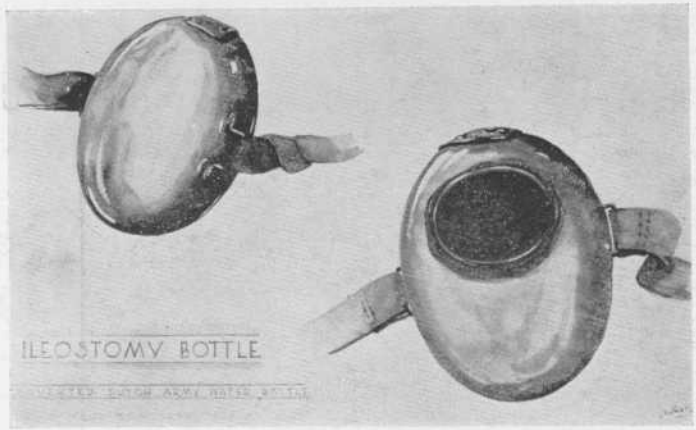
TREATMENT

Treatment has had its disappointments, as well as its dramatic successes. Throughout the war on all fronts the Australian medical services

had to exert the strictest economy of drugs. Emetine and in particular emetine-bismuth-iodide were scarce; the latter was sometimes and in some places unobtainable. The standard laid down originally for the A.I.F in the Middle East was followed as far as possible. A total of 8 to 10 grains of emetine hydrochloride was given, preferably by intramuscular injection, in daily doses of 1 grain in 1 c.cm. of water. A light diet was usually allowed. In acute and subacute infections the immediate effect was most satisfactory. Chronic infections were the least satisfactory to treat. The advice given in the official instructions was usually followed that the patient should be kept in bed during the course and for some days after on account of the possible toxic effects of emetine on the myocardium. No evidence of cardiac disturbance was ever seen, even when such strict precautions were relaxed, and the Australian experience suggests that the importance of this caution has been exaggerated. Emetine-bismuth-iodide was officially advised for use in chronic or relapsing infections and for symptomless carriers who were passing cysts, but it was not used for the latter purpose, owing to its scarcity and the dubious need for it in the absence of symptoms. As a routine the best method was found to be a course of emetine, followed by a course of up to 30 grains of emetine-bismuth-iodide. The usual dosage was 1 grain for 3 successive days and then 3 grains daily for 7 days. An interval of three weeks was considered advisable to allow time for the elimination of the accumulated emetine, but no harm was found on shortening this interval. During convalescence carbarsone 0.25 gramme twice a day for ten days was advised. Later stovarsol was used in place of carbarsone, and no objection was found to giving this drug during the course of emetine-bismuth-iodide or of emetine. Occasional trouble was found with nausea or vomiting following the administration of the latter drug, but by always giving it at night after a sedative, little difficulty was experienced. In general it was found better not to excite any apprehension in the patient and to let him take the dose without special comment. Yatren (Quinoxyl) 2 to 2½ per cent solution was found useful as a retention enema of about 6 ounces, when obtainable, but supplies were restricted. Double iodine compounds such as "Diodoquin" were not readily available, and experience with them in the services was insufficient for opinion as to their value. Where circumstances allowed thorough treatment to be given the results were very good, and relapses were few and much less frequent than after a partial treatment. Emetine alone was sometimes apparently sufficient, but remembering the pathology of the disease the value of emetine-bismuth-iodide with its local action was evident. The value of early and adequate treatment was borne out in Australian experience. There was no advantage in giving repeated courses of emetine where the patient was passing cysts and had symptoms of relapsing or chronic disease. However, when the patient presented signs of acute recrudescence, especially with diarrhoea, a brief series of emetine injections could be used with good results to control acute symptoms, followed later by the other drugs. Amoebic involvement of the liver and lung required the normal full course even if no colonic symptoms

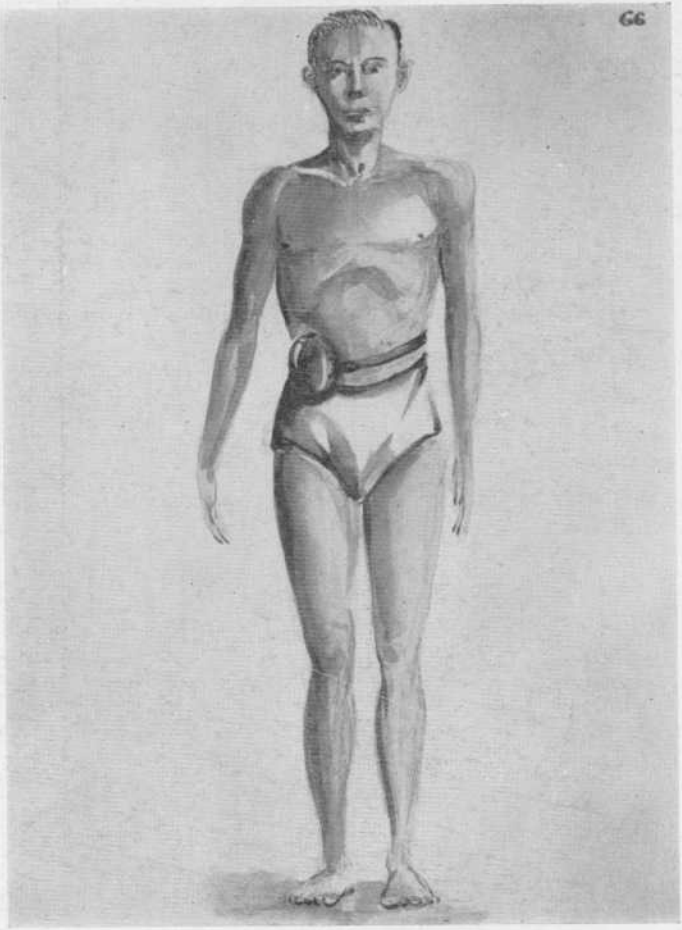


Proctoscopy of amoebic ulcers—Nakom Paton.



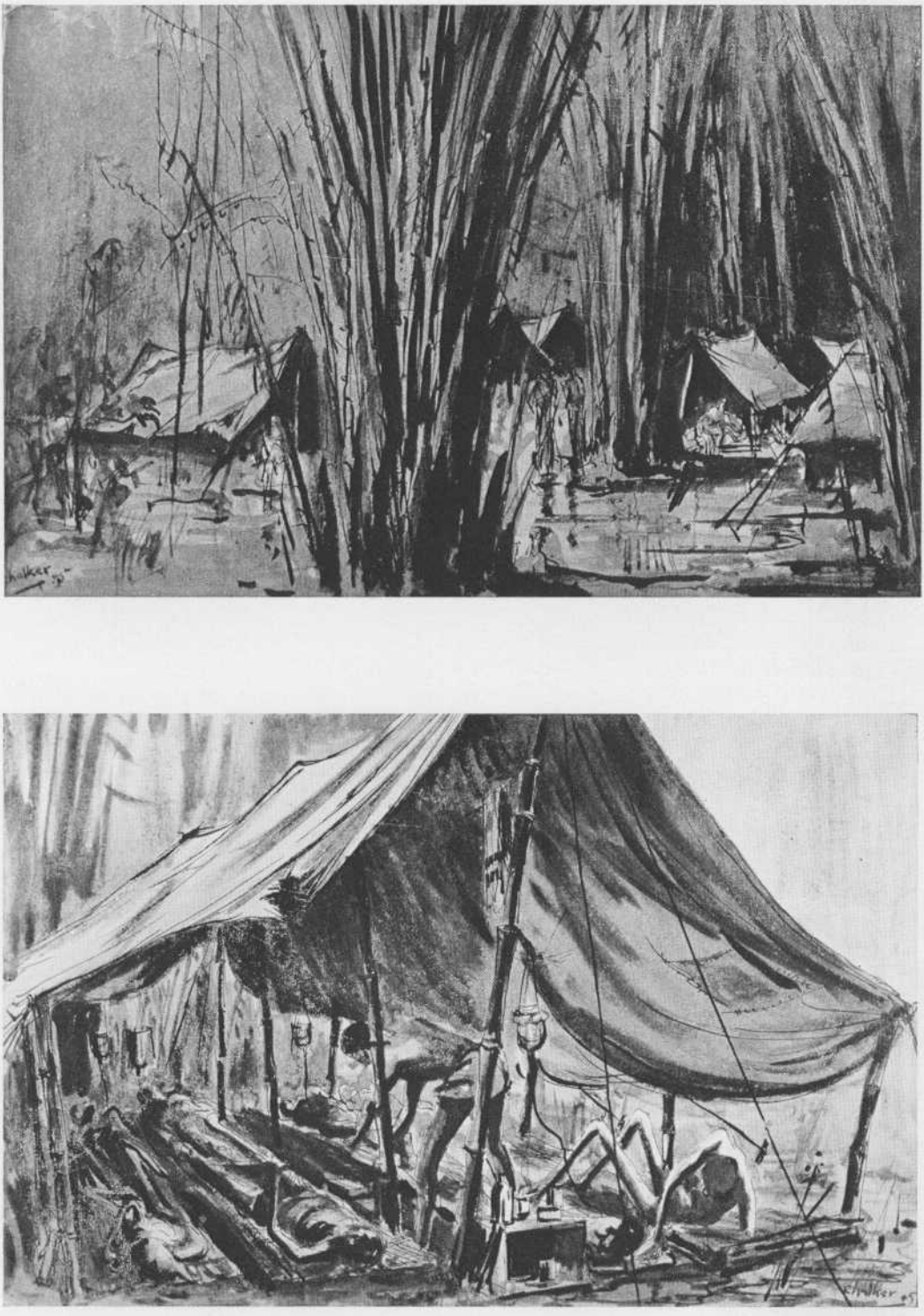
(Drawn by J. Chalker)

Ileostomy bottle made from Dutch water bottle.



(Drawn by J. Chalker)

Patient wearing ileostomy bottle at Nakom Paton.



(*Drawn by J. Chalker*)

Cholera Camp, Hintok.

were present. The specific action of emetine was especially remarked in the more acute and the hepatic forms of the disease. It was gratifying to see temperature fall rapidly, and pain, tenderness, and enlargement of the liver subside after a few injections. Therapeutic trial has been mentioned. The greater the experience of a physician with amoebiasis, the sooner will he try the effect of emetine in obscure illnesses, realising the uncertainty of microscopic diagnosis. Five grains of emetine or less will soon prove whether the diagnostic nail has been hit on the head. Therapeutic response alone is the touchstone, for the drug does not increase the ease of finding amoebae; it is a resolving and not a provocative agent.

Special technical instructions were issued for aspiration of liver abscesses. For the most usual site the upper part of the right lobe, the eighth or ninth intercostal space was advised, in the anterior axillary line, the needle being directed inwards, backwards and a little upwards. For abscesses nearer the lower edge of the liver a combination of laparotomy and needling was safer. Drainage was advised only if secondary infection had occurred. Though amoebic hepatitis was occasionally seen, frank abscess was very uncommon in service experience.

The advanced forms of disease seen under conditions of captivity under the Japanese have been mentioned. Lieut-Colonel Coates had difficulty in persuading the Japanese that amoebic dysentery existed in the camps of Burma and Thailand, but the evidence of deep penetrating ulcers seen *post mortem* eventually produced some effect, and a microscope was obtained to confirm the diagnosis. In Kanchanburi Hospital also the demonstration of vegetative amoebae to a Japanese medical officer helped to get supplies of emetine and Yatren. Emetine was made by Captain Van Boxtel from extract of ipecacuanha, and used with immediate relief in the massive colonic infections, with their devastating haemorrhage and pain. But the appalling prevalence and severity of the disease in these camps made it necessary to seek more radical means of relief, and surgery was undertaken. The chronic infections had lasted in some cases for several years, in spite of drugs, and such patients were greatly relieved by ileostomy which allowed their bowels to rest. Dutch water bottles were used to make improvised ileostomy bottles. Great relief was given by this procedure. Even early infections profited by surgical drainage, where rapid deterioration was taking place, and here appendicostomy or caecostomy enabled irrigation to be used without discomfort. Colostomy carried the risk of causing invasion of the abdominal wall. Further details are given in the section on abdominal surgery. These surgical measures, used under unusual conditions proved life saving in numbers of cases. They also illustrated how, given an opportunity, the body was still able to build up some immunity to the disease. Even some of the extensive and severe infections yielded to later treatment, and were apparently cured. Repatriation medical officers have advised that in all cases of amoebic infection periodic reviews should be made in which radiological, pathological and sigmoidoscopic examination are carried out. Where indications of residual infection are found a further course of treatment will then be given.

STANDARD OF CURE

As a rule patients required some care in hospital and convalescent depots after treatment was finished, chiefly to make good a loss of weight and vigour which was usually considerable. During this period abdominal symptoms should be absent; macroscopic and microscopic examination of the faeces was always carried out. Finally sigmoidoscopy was performed as a final check. Where doubt existed and opportunity offered check examinations were carried out after an interval of some months.

IODAMOEBIASIS

One instance was seen of what appeared to be general infection with *Iodamoeba butschlii*. Dr E. H. Derrick found in a Japanese prisoner of war ulcerated lesions in the colon resembling those of the *Entamoeba histolytica*. In the stomach colon, lungs and brain were also found amoebae which have been considered identical with *Iodamoeba* by Dr C. M. Wenyon. No report on the stool was available, but this evidence indicates that this protozoon can be pathogenic. It is well known as an occasional inhabitant of the colon. The possibilities of *Iodamoeba butschlii* as a pathogen have perhaps been overlooked. Major H. O. Lancaster found that nineteen of 849 soldiers who had served in the Middle East or New Guinea harboured cysts of this amoeba, though more were found in 155 men who had not left Australia. It is known to be an occasional inhabitant of the colon in apparently healthy people. Andrew found *Iodamoeba* in 4 persons who had abdominal symptoms. The *Iodamoeba* has been found to be very susceptible to emetine, but clinical experience is too small to decide the importance of this protozoan as a cause of dysentery. Evidence suggests that where such infection is suspected emetine-bismuth-iodide will be of value.

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CHAPTER 3

FOOD POISONING

FOOD poisoning is here taken to mean an acute illness, usually involving a number of people within a short space of time, and associated by direct or indirect evidence with the ingestion of food. Though the cause may differ widely from chemical to bacterial agents the pattern of symptoms is usually similar, predominantly gastro-intestinal. Botulism is included here because it is derived from food, though the symptoms are neuro-toxic in nature. The various types of food poisoning are grouped thus: (1) epidemic diarrhoea, proven or suspected to be due to bacillary dysentery; (2) *Salmonella* infections; (3) infections by staphylococci or their toxins; (4) other bacterial or possibly viral infections; (5) poisoning by organic or inorganic substances; (6) botulism.

(1) DYSENTERIC INFECTIONS

The value of bacteriological investigations in the field has been shown by occasional outbreaks of bacillary dysentery which simulated other types of food poisoning. In New Guinea in particular outbreaks of an explosive kind have been seen, in which vomiting, diarrhoea and abdominal pain have attacked a number of men within a short period. Though the clinical history has sometimes suggested other forms of food poisoning, by reason of a short incubation period, a rapid course, and simultaneous occurrence in a group of men, cultures of true dysenteric organisms have been grown on occasion.

(2) SALMONELLA INFECTIONS

The group of *Salmonella* infections causing continued fever has been described in the section on enteric fevers. These differ from the *Salmonella* infections of the food poisoning type by their longer incubation period and by their longer, more serious course. Some of the *Salmonella* group such as the *aertrycke* type were believed to be responsible for numbers of outbreaks of food poisoning in the Services. A technical instruction was issued by the D.G.M.S., Army, on the general subject of food poisoning. In this it was pointed out that *Salmonella* infections were known to be an important cause, though demonstration of the exact organism and of its method of transmission was often difficult. Massive infection with living organisms probably occurred, through contamination of foodstuffs especially those whose preparation involved handling, such as ham, salt beef, and in particular warmed-up food. In Darwin one outbreak was traced to either mince or rice. Storage of food at temperatures over 65°F. is known to predispose to development of the organisms, and this frequently occurred in tropical climates. Rats and mice have been blamed for spread of this type of food poisoning, and probably flies also. While human carriers have apparently not been specially blamed in all such outbreaks of infec-

tious food poisoning, there was a growing realisation in the services of the importance of looking to the method of handling and preparation of food as a source of trouble.

The symptoms produced were those of a sharp attack of gastro-enteritis, with vomiting and diarrhoea. The incubation period was short, twelve to twenty-four hours, which often enabled the infection to be traced with reasonable certainty. As the organisms are rapidly eliminated such outbreaks usually subsided quickly, and did not spread widely. The greater persistence of *Salmonella enteritidis* and the finding of occasional human carriers of other types as Draper has shown dictate caution where outbreaks have occurred. Sulphaguanidine and other sulphonamides have not been found effective in the treatment of *Salmonella* infections in general, though the former has given good results in some outbreaks of *Salmonella cholera suis* and *paratyphoid A*.

(3) STAPHYLOCOCCAL POISONING

Similar kinds of food could also be infected with staphylococci, which caused characteristic symptoms. In *Salmonella* infections it is the living organism which causes the symptoms, but in staphylococcal infections both the living organism and its toxin can cause illness of distinctive kind. Therefore cooking of food is not necessarily a safeguard if it has been previously infected. Here again food handled in preparation especially by anyone with staphylococcal infection of the hands or food stored at too high a temperature may be massively infected, and though the organisms will not survive efficient cooking their exo-toxin may. W. J. Scott and D. F. Stewart, investigating the question of contamination of foodstuffs for the Council for Scientific and Industrial Research, found that in one instance hams stored at 80°F. had been infected with a strain of *Staphylococcus aureus* which produced a potent toxin. Sangster and Constance described an outbreak among troops which illustrated the usually distinctive features. Numbers of similar outbreaks of this kind occurred in the Services, in which the rapid onset, severe initial symptoms and rapid recovery were exemplified. The incubation period was usually a few hours only or even one hour. Abdominal pain was followed by faintness, vomiting and diarrhoea. Vomiting was sometimes exhausting and persisted for several hours. Not infrequently a large loose stool was passed at the beginning of the attack, with signs and symptoms of collapse. Occasionally the onset was one of dramatic severity, and even in less severe attacks physical weakness was often extreme for a short time. In Sangster and Constance's series 23 men were admitted to hospital within thirty minutes; they were quite well within two or three days. Another outbreak of undetermined but probably similar origin caused the rapid collapse of 170 patients in a United States Army train after eating stew. On an army transport lying at Colombo over 400 men were simultaneously attacked during the night, and lay about the decks in lamentable discomfort, possibly heightened by mass suggestion. This outbreak did not affect officers or N.C.O.'s and some of the affected men had not been ashore. The cause was not ascertained

but was possibly staphylococcal. Another outbreak occurred in an L.S.T. at Tarakan and was traced to meat sandwiches. Though milk foods are supposed to be a commoner vector of this affection than meat, the latter seemed to be the usual source in service experience.

(4) OTHER EPIDEMIC FORMS OF GASTRO-ENTERITIS

Epidemics of gastro-enteritis occurred in many parts of the world during the war years which could not be traced to known bacterial cause. The suggestion has been made that a virus might be the cause. Service experience can shed no light on this suggestion. It was found that even when the bacteriological cause of an outbreak of diarrhoea was proved the organism was isolated only with considerable difficulty in the milder infections, especially towards the end of an epidemic. Civilian experience has also shown how difficult it may be to discover and isolate the causal organism in some of the severe epidemics of diarrhoeal disease in young babies. This form of gastro-enteritis appears to have been occurring in adults also in the civilian community, and with a greater prevalence than before the war.

(5) POISONING OF CHEMICAL ORIGIN

Under this heading are included only conditions whose symptoms simulate infective disease derived from foodstuffs.

An outbreak of a gastro-intestinal disorder in Egypt suggested by its symptoms the possibility of a metallic poison taken accidentally in food, but no evidence was found. All the men recovered quickly.

A number of vegetable poisons were known to exist in Northern Australia and New Guinea. Mostly the toxic effects observed affected the skin by contact, and reference will be made to these in the section on dermatology. Booklets describing the edible and non-edible plants in New Guinea, compiled from intelligence summaries, were published by Land Headquarters for information. Very few instances were encountered of illness due to poisoning by local fruits or nuts. Simple diarrhoea was caused sometimes in New Guinea by an excess of fruit, such as paw paw, and prisoners of war in Japanese camps sometimes suffered from mechanical diarrhoea caused by the eating of indigestible material through sheer hunger. At Lae symptoms of poisoning were observed to follow the eating of some native nuts, such as the "candle nut" which contains croton oil. On one occasion twelve men were affected with severe abdominal pain and tenesmus, passed blood and mucus in the stools, and suffered from severe shock. Six of them required some fluid replacement by glucose and saline solution or blood.

H. Flecker drew attention to the possibility of troops in Queensland being poisoned by the "Finger Cherry" (*Rhodomyrtus macrocarpa*), which has in rare instances caused blindness. As the fruit is only occasionally poisonous it has been suggested that only unripe fruit is toxic, or that

the symptoms are really due to a fungus growth. No instances of poisoning were seen in the Australian Services.

Surgeon-Lieutenant Begg drew attention to the possibility of poisoning by potatoes (solanine poisoning). While H.M.A.S. *Warramunga* was en route for Noemfor in June 1944 twelve out of seventeen ratings were suddenly attacked by severe abdominal pain and watery diarrhoea, without the passage of blood or mucus. A conspicuous feature was the extreme weakness of the men, who were unable to walk. The only evidence was circumstantial, but the only men affected were those who had eaten boiled potatoes. These vegetables were the last of a batch a month old; most of them were sprouting, and some had been discarded as bad.

(6) BOTULISM

One outbreak of botulism occurred in the Australian Army in the Northern Territory. Instances of faulty tinned food were occasionally seen in various areas. An Australian mobile bacteriological laboratory reported the growing of an organism consistent with *Clostridium botulinum* from "blown" tins of ham prepared in Australia. However, it was pointed out in the Technical Instruction No. 61 that in botulism, as in staphylococcal poisoning, the symptoms may not be due to living organisms but to toxins generated in the infected food. In each case sufficient time must elapse between the implantation of the infection and the production of the toxin. For this reason particular care was advised with warmed-up food.

A suspicious series, probably due to the same cause, occurred in United States troops in Iron Range, Queensland. Seven men died as a result, but examination of 400 tins of suspected beetroot did not reveal any *Clostridium botulinum.*

The Australian cases were undoubtedly due to botulism. Halliday reported the admission of five soldiers to hospital in Adelaide River, Northern Territory, with symptoms of initial gastro-enteritis followed by signs of involvement of the central nervous system. These men made sandwiches of tinned beetroot, but noticing a curious brownish colour and an unpleasant taste they spat it out, only one of them swallowing a mouthful. Two were only slightly upset and recovered without developing any nervous symptoms. Another man vomited and three days later had blurred vision and discomfort on swallowing, but recovered fully in a few days. Two other men were seriously ill and one died. The latter fell ill in thirteen hours with vomiting and cramps, and the following day had difficulty in speaking and swallowing. These signs progressed, ptosis appeared with mental dullness and cyanosis, and he died on the fourth day. The other man had blurred vision as his first symptom on the second day and dysphagia and ptosis followed. There was considerable weakness of the muscles of the limbs. No abnormality was found in the cerebro-spinal fluid. After a month he had practically recovered, but was still debilitated.

Though no organisms were grown from any tins examined there was no doubt about the source of this infection. The use of bent, rusty, swollen or leaking tins was prohibited, and instructions were promptly issued for-

bidding the consumption of tinned beetroot. The canning process was investigated and improved, and the accumulated remainder of unused tins was dumped at sea. No further cases of botulism occurred.

Notes were given to medical officers of points useful in the differential diagnosis of food poisoning, particularly with regard to the incubation period and type of symptoms. The power of food poisoning to light up a dysenteric infection was particularly stressed. Methods were detailed which would help in the investigation of any outbreak, including full clinical details, study of the implicated food, collection of the actual food consumed, and of specimens useful for bacteriological investigation.

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CHAPTER 4

CHOLERA

THE possibility of cholera was early realised as a menace to troops engaged in campaigns in the islands on the northward route to Japan. It was evident that by traffic to or from the endemic areas such as Celebes, Burma, Malaya, Indo-China, the Philippines and Japan the disease could be introduced. The Combined Advisory Committee in Tropical Medicine, Hygiene and Sanitation which was set up to give expert guidance to General MacArthur discussed the problem at its first meeting in March 1943. At that time the situation was not dangerous, but steps were taken to assure ample supplies of cholera vaccine, should general inoculation of troops be necessary. Early in 1944, however, the position had changed and the committee's intelligence section showed that cholera had advanced rapidly beyond its pre-war boundaries. During 1943 there were severe epidemics of the disease in Shanghai and Hong Kong, and from Formosa it had spread by sea routes to the Carolines, Singapore and Makassar in the Celebes, and later in this year was spreading widely through the Philippines.

The committee drew the attention of General Headquarters in the South-West Pacific Area, and of the Australian Government to the position. It was apparent, therefore, in 1944, that definite plans were necessary; these included inoculation of troops, provision of special supplies and equipment, especially for bacteriological diagnosis, provision of adequate quarantine facilities, and special training of medical staffs in the recognition and handling of the disease, and of troops in hygiene. The Australian Armed Services obtained supplies of cholera vaccine sufficient to inoculate men serving beyond Australia. The American forces were already being inoculated, had promulgated instructions and obtained all equipment necessary. In June 1944 the committee recommended that similar measures be taken by the Australian medical services, and urged that medical advance units entering new areas be alert to detect any suspicion of an outbreak of cholera. The Royal Australian Navy decided on inoculation of all men entering endemic areas, and arranged for two injections to be given to all personnel except those in category "X", with a further stimulating dose every six months, or when considered advisable by the medical officer. Such army and air force men were inoculated as were exposed to the risk of infection in endemic areas.

Comprehensive technical instructions had already been issued through the Australian Army Medical Services, and details of standard procedures were circulated by the Deputy Assistant Director of Hygiene of New Guinea Force. In these instructions it was pointed out that certain of the features of cholera carried special risk to military formations. Areas might be infected by members of enemy forces who were incubating cholera, actually ill of the disease or convalescing from it. In the last mentioned case carriers were a danger, as 10 per cent of convalescents were infective

for about two weeks and some for months. Troops might be obliged also to occupy endemic areas. Epidemics might spread by carriers along lines of communication, and cholera vibrios under favourable conditions might remain viable for weeks and infect food or water in the usual ways. Water-borne infection was a particular danger because of the explosive nature of outbreaks spread thereby. Emphasis was laid on the importance of regarding standards of hygiene in units or formations in the prevention of other less dangerous intestinal diseases as a measure of their potential protection against cholera. These standards depended on the degree of education of all ranks, and on the hygienic discipline enjoined by the commanding officers, on whom the responsibility really lay. One weak link in the chain of water sterilisation was pointed out in New Guinea Force, the practice of chlorinating only water designed for drinking purposes, whereas unboiled or unchlorinated water was often used in the preparation of food, for cleaning the teeth, or for rinsing mess gear. Partial chlorination had been taught in some army hygiene schools, but with the risk of cholera looming such teaching called for revision. As a result the education of personnel in medical field units was undertaken so that bacteriological diagnosis might be made as early as possible, and cholera teams formed to deal with cases. A summary of necessary laboratory procedures was circulated for information. Fortunately epidemic cholera never became a problem in Australian forces in the Pacific area, but the preparations made were a necessary precaution.

Full instructions for treatment were also circulated. These depended for their efficacy on the carrying out of the procedures designed to make good the dangerous and often lethal losses of body fluid. It is interesting in passing to note that the serious degree of dehydration in cholera and the measures necessary to combat it were described by O'Shaughnessy in 1831. He remarked on the great loss from the blood plasma of water, salt and free alkali, owing to their passage through the bowel, and recommended the restoration of salt and water by enemata or intravenous infusion.[1] In all Australian medical holding units these measures could be carried out. The criteria were blood pressure and specific gravity of the blood, the latter being readily measured by the copper sulphate method, which was a standard procedure. A specific gravity of 1,063 or a systolic blood pressure of 70 mm. of mercury was taken as an urgent indication for parenteral fluid, one litre every four hours, or more if required. A blood pressure of 100-110 was aimed at and a specific gravity of the blood of less than 1,062. Rogers's method of the use of hypertonic saline and the administration of four times molar sodium lactate for threatened renal failure were described and advised. An interesting point was raised touching anti-cholera propaganda, whether such preparations and precautions would increase fear and perhaps lower morale. There is no evidence that it did so in any way, in fact the effect on hygiene was good. As early as 1942, when the 7th Australian Division was in action on the Owen Stanley

[1] I am indebted to Dr Robert F. Loeb for this reference, embodied in a communication made from the clinic of Dr Dana W. Atchley and himself in the Presbyterian Hospital, New York.

Ranges, efforts were made to make all ranks conscious of the risks of untreated water. Warnings of cholera were issued at this time; the effect of this publicity was to make the men more careful, but never did it cause alarm.

Though no emergency due to cholera occurred in 1944 or 1945, study of the ominous spread of the disease from various focal points, and of its extension to zones not usually included in endemic areas showed how epidemics might have flourished in the rapid movements of modern warfare.

The risks of cholera had already been recognised by British and Australian medical services in Malaya during the initial period of preparation and training there. After the capitulation of the forces the danger became reality. On 28th June 1942 a combined administrative instruction was promulgated from the headquarters in Malaya. This warned that the Japanese Army had reported the occurrence of cholera in Singapore, and called for strict observance of precautionary measures. These included the usual precautions concerning water, fruit and vegetables, cooking and eating utensils, control of all men with symptoms of diarrhoea, anti-fly measures and inoculation with cholera vaccine.

In the working camps cholera appeared and caused great loss of life. The conditions prevailing, especially at the approach of and during the damp monsoon season, were only too favourable for cholera, which was introduced by Asiatic coolies into numbers of areas. Little could be done to prevent its spread except with the concurrence and help of the Japanese, whose attitude was inconsistent in the extreme. Coolies lay dying or dead of cholera in close proximity to the insanitary quarters of the European prisoners of war. Great difficulty was experienced by our men in restoring or maintaining reasonable hygiene in the absence of material or labour, especially as all available men, whether ill or not, were absorbed in railway construction and similar work. Though the Japanese were afraid of cholera and had mobile cholera laboratories equipped for diagnosis, they sometimes refused to admit its existence in an area in spite of obvious evidence. Permission was also refused to dig adequate latrines until an epidemic had actually started. Mass bacteriological examinations were conducted on numbers of occasions, cultures being made from a glass rod introduced into the rectum. Vaccines were supplied, but the period of immunity was thought to be short; one Japanese medical laboratory officer placed the period as low as four weeks. This estimate is unduly low for an effective vaccine. Major Bruce Hunt, after extensive experience, considered that an appreciable degree of immunity began some ten days after the first dose, and two weeks after the second dose given a week later, immunity was almost complete and remained so for about three months. After this it slowly waned, and troops then exposed to infection were subjected to risk thereafter. Check smears were made on convalescent patients, the ideal standard of cure being three negative tests, but these were done in a very irregular fashion. Though inoculations were frequently carried out, uninoculated men were with great inconsistency introduced into highly

infected areas. Infection of food and water was almost inevitable in such circumstances, notwithstanding prohibitions by the Japanese of bathing in or drinking river water. On some occasions a five day cycle was observed between peaks of infection, and second waves of the disease sometimes arose in camps to which apparently "fit" men had been allowed to return. In some camps severe outbreaks took place with many deaths. Major Hunt has pointed out that in spite of the inconsistencies and neglect of the Japanese in matters of hygiene, their soldiers were trained to keep their mess gear scrupulously clean, to immerse it in boiling water before use, to drink only boiled water and not to eat with their fingers. The Australian soldiers tended rather to regard hygiene as chiefly the responsibility of hygiene squads, and greater personal responsibility in their training would have been advantageous in conditions prevailing in Burma and Thailand. Isolation quarters for cholera in this camp, as in others, were sited in marshy jungle, and only half protected from the rain, which poured through leaky huts and tents on sodden improvised beds. In the absence of blankets or groundsheets bamboo platforms were all that could be improvised, and as lights were almost non-existent, the chaotic and primitive conditions of the only nursing possible, particularly at night, can hardly be imagined.

As is usual in cholera epidemics the onset of the illness was tragically rapid in many men, who collapsed at work and elsewhere without warning, and sometimes were dead in a few hours. Men who were struck down suddenly were ordered by the Japanese to be left where they were till removed by the meagre hospital staffs, often over a considerable distance. The delays and hardships thus imposed lost many lives. Segregation of suspects was most difficult, as diarrhoea from other dietetic causes was almost universal in some camps. Facilities for boiling or chlorinating water were most inadequate. However, attempts were made to limit the spread of infection as far as possible by the control of the water supply and by sterilisation of mess gear, and nursing was carried out by volunteers with great devotion. A number of these volunteers lost their own lives from cholera. The classic pictures of cholera were seen in these outbreaks, with the extraordinarily rapid and overwhelming prostration, the copious vomiting and purging, with the characteristic pale fluid evacuations.

Dunlop, Hunt and others have described the early features of cholera as seen in these camps. Some details of the clinical picture were rather different from the average, possibly owing to the pre-existing debility of the men. Many of them already had diarrhoea before the onset of cholera. Vomiting was not always frequent, but in the early stages sudden faintness was common, with ringing in the ears, deafness and dimness of vision. The voice was faint and hoarse, and the whole appearance apathetic. Before the onset of cramps a firmness of the muscles was often detected. Later severe muscular cramps were frequent, and the men often passed swiftly into the algid phase, in which the sunken eyes and wrinkled skin, so easily seen on the hands, plainly showed the urgent danger of extreme fluid loss. Though men dying of cholera are often painfully conscious till

the close, many of these men died in that state of "coma vigil" once known to earlier students of typhoid fever. In many cases death followed a phase of fever and delirium. Those patients who survived usually suffered from oedema due to deprivation of protein. Uraemia was common as a terminal event, and was also an occasional late manifestation after apparent recovery. It was observed that some of the men who succumbed most quickly became cyanosed and shrunken despite little external fluid loss.

Under prevailing conditions any efforts made to restore the fluid balance of the body were perforce crude, but saline was administered intravenously to many patients and saved many lives. Salt solutions were sometimes made with distilled water, sometimes merely by boiling ordinary kitchen salt or rock salt in water, using rain water or even river water. These fluids were introduced into the peritoneal cavity with a syringe in some instances, and given intravenously in others. Distilled water was made from improvised stills, stolen petrol pipes being used for the coils and these being cooled with bamboo jackets and circulating water. In one camp the Japanese made a still available in a mobile laboratory. In Hintok 120 pints of saline solution were made in twenty-four hours by unceasing work, night and day. Great ingenuity was exercised in the making of intravenous sets from material at hand. Two medical officers of "F" Force, Captain Roy Mills, A.A.M.C., and Major W. J. E. Phillips, R.A.M.C., originated a cannula made from bamboo. Captain Mills used an old tin can, stethescope rubber and bamboo cannulas made with a penknife, and with this equipment saved many lives in a party of 700 men attacked by severe cholera. Hypertonic solutions were used in some areas, double strength saline being employed, but these were more difficult to control. Potassium permanganate was tried in treatment, crystals wrapped in cigarette paper being administered, but it was abandoned, as it was disagreeable to the patients and ineffective. Morphine was prized when available, but was usually very scarce.

The mortality from cholera in these camps was about 40 to 50 per cent. In Hintok Camp 150 men were attacked out of 1,000 and 63 died. In Shimo Sonkurai of 2,000 men 220 had frank cholera and 105 died. There were probably another 250 who had mild infections. Even some of these figures, considering the circumstances, could be regarded as an achievement. The potential killing power of cholera was only too evident; in one outbreak among hospital patients in Tarsau the death rate rose to 80 per cent. Many men succumbed to a terminal attack of cholera following on other intercurrent nutritional and infective diseases. Deaths of men who had had cholera also occurred from malaria, dysentery and nutritional deficiencies long after the epidemic waves had passed.

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CHAPTER 5

FEVERS OF THE ENTERIC AND RELATED GROUPS

TYPHOID AND PARATYPHOID

AT the outbreak of war in 1939 the enteric fevers were not thought to raise any serious military problem, owing to the striking success of immunisation. The classic example of the value of immunisation was, of course, the South African war in which the incidence rate was 288 per 1,000. The proof then obtained that this enormous rate could be reduced to negligible level was amply sustained in later experience. During the 1914-1918 war, Australian troops on the Western Front showed an incidence rate of only 0.38 per 1,000, thanks to the adoption of a prophylactic combined vaccine for typhoid, and paratyphoids A and B. Since then much more has been learnt about the antigenic structure of bacteria, and experience has taught the need for using a vaccine which is antigenically potent. The introduction of a "Vi" antigen from virulent strains reduced a small but not negligible death rate from enteric fevers in the British Army in India to vanishing point in the years immediately preceding 1939. During 1939 and 1940 typhoid fever was unknown in the British Expeditionary Force in France, and the same vaccine used for these troops was also used for British troops in the Middle East.

In Australia, when the Second A.I.F. was first being recruited, inoculation was made compulsory. The dosage to be used was then discussed, attention being paid to the severity of local and general reactions and to the degree of protection gained. The vaccine used was the standard "T.A.B." vaccine of the Commonwealth Serum Laboratories, containing in each cubic centimetre 1,000 million *typhosus* and 500 million each of *paratyphosus A* and *B*. The usual doses given by the subcutaneous route were 0.5 c.cm., 1.0 c.cm. and 1.0 c.cm. at weekly intervals. Severe reactions were not unusual, and on the advice of Colonel C. H. Kellaway, Director of Hygiene and Pathology to the Army, these doses were reduced to 0.25, 0.5 and 0.5 c.cm. Even these lower doses produced some sharp reactions, but not to an inconvenient degree, and it was thought that the immune response would be sufficient. Colonel Kellaway suggested the advisability of adopting a detoxicated vaccine, but the staff of the Serum Laboratories preferred the ordinary vaccine. A further question was debated at this time, that of the practicability of using a "cocktail" vaccine combining enteric fevers and tetanus. General Downes, D.G.M.S., during a recent trip overseas had received favourable reports from its use in the French Army and wished to try it in Australia. Later such combined preparations were tested on volunteers, but as the reactions were apt to be unduly severe and the immune response was not always satisfactory, the method was never adopted. It is of course evident that uncomfortable side effects of a vaccine are undesirable, but its effectiveness is vital.

Some doubts were felt in Australia that the lessened doses of "T.A.B." might be insufficient for full protection in countries where the risk was considerable. Tests were made by Colonel Kellaway on three separate groups of volunteers, and these showed that the average range of the agglutinin titre of the blood serum for typhoid O was not satisfactory. These results fell below the standard maintained by the British vaccine, prepared by the Royal Army Medical Corps College. Kellaway therefore advised the administration of an additional dose of 1.0 c.cm. to all members of the A.I.F. overseas.

During 1940 the number of cases of typhoid in the A.I.F. in Palestine and Egypt was not undue, the rate being 0.49 per 1,000. But in 1941 it had risen to 1.05, and 80 cases were reported from an average strength of 76,440 troops. It was shown that the hazard of infection was greater, especially in campaigns in countries like Greece and Syria. In Greece and Crete enteric fevers were relatively common compared with other European countries, and the circumstances of the military actions there made chlorination of water difficult. Up to the time of the evacuation only ten cases were known in the A.I.F. in Greece, but five were fatal, owing at least in part to the exhaustion of the men and the late period at which they reported sick. None of these men had been immunised since the end of 1939. A.I.F. hospitals in Palestine cared for a number of members of the Greek Air Force who had not been inoculated: all contracted virulent infections.

In Syria and the Lebanon too the risk was considerable. The mortality rate among natives was given as 10 to 15 per cent, and among newcomers to the country it was higher. In the large towns water supplies were piped and were usually satisfactory, though the hygiene in certain quarters of the same towns was usually poor and fly-borne infections readily occurred. In the villages water supplies from springs and wells were sometimes polluted, and local epidemics occurred. In Beit Meri, for example, a pleasant hill resort near Beirut, military personnel were quartered in the hotels, and their safety was endangered by a severe outbreak among the local inhabitants of a neighbouring village. But even these risks should not have been sufficient to raise the incidence rate of enteric fevers, which compared unfavourably with that of the British forces, even though the inoculation of the latter was not at the time complete. Instances also occurred of infection among nurses and other members of the staffs of hospitals where patients with typhoid were being nursed. On 12th September 1941 twenty-four patients with proven typhoid or paratyphoid fever were being treated in the 2/7th Australian General Hospital.

Colonel J. S. K. Boyd was asked to carry out mouse-protection tests using the Australian vaccine and comparing it with the British. These showed that insufficient protection was afforded by the Australian vaccine against virulent cultures: it therefore appeared that this vaccine was deficient in Vi antigen. Steps were immediately taken to have a virulent strain sent to Australia to replace that used for production of vaccine.

The strain originally obtained for the purpose had been virulent, but Boyd and Keogh considered that virulence might have been lost by mass culture on media not adapted for the maintenance of the organism for the purpose of antigen production.

One interesting experience, possibly illustrating the same point of the importance of a potent Vi antigen for immunisation, was in connection with Italian prisoners of war in Egypt. Some 700 were attacked by typhoid and paratyphoid in spite of being inoculated and re-inoculated with Italian T.A.B. vaccine. After re-inoculation of the prisoners with R.A.M.C. vaccine the epidemic ceased.

During the time which would elapse before a fully potent vaccine became available from Australia, arrangements were made to give members of the A.I.F. in the Middle East a refresher inoculation of 0.5 c.cm. of the British vaccine. Adequate precautions were advised to ensure maintenance of full antigenic potency of the T.A.B. vaccine for future use. This experience showed the risk of exposure to virulent strains of the enteric group without full immunisation.

In 1942 from an average strength of 41,594, 21 cases of enteric fevers occurred, a case incidence of 0.50—half the rate of the previous year.

The diagnosis of this group of fevers was the subject of a special instruction, stress being laid on the importance of early blood cultures. Tests for rises in agglutinin titres of the serum were of course apt to be misleading in inoculated subjects, in whom they are of little discriminative value in diagnosis. In this work the value of pathological services were great, and in areas like Syria, where an occupying force faced considerable hazard of infection, the presence of a mobile bacteriological laboratory was most helpful. In such areas, where there were no general hospitals, considerable strain was thrown on holding medical units. In the 2/3rd C.C.S. in Beirut, for instance, thirty-three patients were treated for enteric fevers between August 1941 and January 1942, and at one time there were sixteen in the wards. These patients came from sewered and unsewered areas in equal numbers. Four were infected with paratyphoid of various types, and the remainder with typhoid. Three patients died. Considerable benefit was found to occur from the use of convalescents' blood and serum, up to 300 c.cm. serum or two pints of blood.

Before passing on to consider infections by members of the enteric groups of organisms other than typhoid, it is instructive to compare the impact of typhoid fever as a concentrated epidemic attacking an unprotected civil community.

In 1943 an extensive civilian epidemic of typhoid fever occurred at Moorabbin, a semi-urban, semi-rural area near Melbourne. It began with a few cases only, seven being reported in ten days, and two days later with a striking explosion of activity the epidemic began, sixty-nine patients being admitted to hospital in one day. Dr C. R. Merrillees of the Department of Public Health in Victoria investigated the outbreak and soon traced its source to milk from one dairy. It was significant that no cases were traced from a milk-bar in the neighbourhood; the milk came from

another source of supply. The wife of the occupier of the suspected farm was proved to be a typhoid carrier. The prompt closing of this dairy stopped further spread of the disease, but between March and the end of July 1943, four hundred and thirty-three persons were infected with typhoid fever, twenty-three died and thirteen remained carriers. The affected area had a population of 4,500 out of a total of 24,000 in the whole Moorabbin district. During the same period only twenty cases of typhoid were notified from the rest of Victoria.

This epidemic shows clearly the danger of the carrier, and the greater dangers of the careless handling of foodstuffs, and contrasts sharply in its rapidity of spread and its violence with outbreaks in a population with some degree of immunity. The resources of Heidelberg Military Hospital were made available in coping with this epidemic. Numbers of civilian patients were admitted and cared for there, and members of the Australian Army Nursing Service were detailed to help in other hospitals. In the treatment of these patients intravenous injections of T.A.B. vaccine were used, and in the opinion of the medical staff good results were obtained.

Even with the threat of rising rates of enteric fevers in 1941 the numbers were never high, and fell throughout the war years as the following rates for each year show:

A.I.F.	1940	0.49	per 1,000
	1941	1.05	„ „
	1942	0.50	„ „
A.M.F. (in Australia) .	1942	0.14	„ „
A.M.F.	1943	0.11	„ „
	1944	0.03	„ „
	1945	0.10	„ „

During the war in the islands some concern was felt lest "new" strains of enteric organisms derived from the Japanese might infect our soldiers. Investigation of captured documents showed that despite frequent inoculation against typhoid and paratyphoid A, Japanese troops suffered considerably from these diseases. In Rabaul in 1943 paratyphoid A was said to be "the third most prevalent contagious disease". Presumably insufficient protection was conferred by the vaccine they used.

Few proven paratyphoid A or B infections were seen in Australian soldiers, though it is possible that these were more common than was apparent. In 1942 a number of patients in the 113th Military General Hospital at Concord suffered from febrile attacks of diarrhoea with blood and mucus. No organisms were grown but in two instances agglutination of *paratyphosus A* was demonstrated in the serum, up to a titre of 1 in 320, and in two others *paratyphosus B*. One of the former patients died, and ulceration and gangrene of the ileum were found.

In 1943 at Katherine in Northern Territory paratyphoid B appeared, being at first detected in an aboriginal and a civilian. Shortly afterwards a sudden outbreak of "gastro-enteritis" occurred in the wards of the 121st Australian General Hospital. The symptoms were fever, abdominal colic,

vomiting and diarrhoea, though the last-mentioned signs were not always present. The illness was brief, lasting only thirty-six hours. From three patients *paratyphosus B* was grown on culture; one of these men had no diarrhoea, but had an effusion in the knee joint.

SALMONELLOSIS

In New Guinea in the latter part of 1942 enteric-like fevers were being observed which were not due to typhoid or the paratyphoids A and B. Some of these patients were admitted to hospital in the first place for malaria and found to have a continued fever. It soon became evident that another type of specific infection was occurring, and bacteriological examination established that a constant strain of the *salmonella* group was responsible. The occasional presence of metastatic lesions and the recovery of the organism from the blood, the bowel and the local lesions were characteristic of infections by the *Salmonella enteritidis,* which was revealed as the cause by investigations on the mainland.

A considerable degree of toxaemia was a feature of this illness: some of the patients were at first thought to be suffering from typhus. Abdominal symptoms were usually present, chiefly discomfort, distension and looseness of the bowel. An eruption of pink macules was occasionally seen, chiefly on the trunk and lower extremities. Broncho-pneumonia was an infrequent complication: it was found in six out of a series of fifty men studied by Fenner and Jackson.

Three types of infection by *Salmonella enteritidis* were exemplified in New Guinea, a continued febrile illness resembling enteric fever, a gastro-enteritis of short duration with fairly rapid recovery, and a severe septicaemic variety in which metastatic complications were frequent. The second of these is mentioned further in the section on food poisoning and it differs *inter alia* from the continued febrile type in having a brief incubation period. Actually there is no clear distinction between the other two varieties, as metastatic inflammations occurred in many of these infections of the continued febrile type. These were often suppurative and tended to prolong the course of the disease, which was otherwise some two or three weeks. Cystitis was not uncommon, pus appearing in the urine, from which the organism could often be grown. In six of Fenner and Jackson's fifty cases epididymo-orchitis occurred, and in four periostitis or perichondritis. In a few instances subcutaneous abscesses formed, and this suppurative tendency was seen on one occasion in a small abscess at the site of puncture of a vein. The infecting organism was grown also from these lesions. Empyema occurred in two cases of this series, also cholecystitis in two cases, in one of which drainage was necessary Jaundice occurred at times. A relatively slow pulse was usually observed. No striking change was found in the blood cells, the leucocyte count being usually about 8,000 per c.mm. Brachial arteritis was observed in one patient; it resolved after causing threatening symptoms. On one occasion suppurative pericarditis was found, and was successfully treated by Cobley and Wilson with penicillin. Except for these complications the fever

usually resolved in some three weeks, but three men died. Material was available only from one autopsy: no evidence of intestinal ulceration was found. Diagnosis was best made by early blood culture, and agglutination tests were not helpful in this regard except in identifying the organism after culture. An army technical instruction (No. 56) was distributed to inform medical officers that this infection was occurring and to indicate diagnostic methods. An agglutinating serum for *Salmonella enteritidis* (*Gaertner*) was available, thus simplifying diagnosis in the field. This instruction pointed out that the organism could be cultured from the blood, the faeces and the urine, and might persist in the urine for weeks. One soldier who had a complicating cholecystitis continued to pass the organisms in the faeces.

The epidemiology of this infection had some interesting features. It appeared in New Guinea late in 1942 on the Owen Stanley Ranges and early in 1943 at Buna on the coast. A smaller outbreak occurred on the Huon Peninsula in 1944, and other sporadic infections were recognised in various places in the islands. In March 1945 for instance there was an outbreak in Bougainville. Ferris and Hertzberg also described a series of these infections on the Atherton Tableland in Queensland in which the chief presenting symptoms were abdominal pain and diarrhoea not controlled by sulphaguanidine.

In 1944 the disease was demonstrated in natives of New Guinea, in whom it occasionally proved fatal. It had not been previously recognised in New Guinea, although much investigation of febrile diseases in natives had been carried out. It is possible therefore that the infection was introduced to the island during the war years. The most probable method of spread was thought to be by human carriers: in one instance at least the evidence pointed strongly to a human vector. Infection was probably transmitted by food. Rats and mice are known to carry these infections, and this possibly cannot be disregarded. There were plenty of bush rats in New Guinea, though there is no evidence to incriminate them. In the Base Military Hospital in Melbourne in 1944 an epidemic of *Salmonella enteritidis* was recognised among laboratory mice.

Investigation of the cultures from twenty-three patients by Nancy Atkinson at Adelaide showed that the strain was the *Blegdam* variety of *Salmonella enteritidis*. A strain isolated from an outbreak at Atherton was found to be of different antigenic structure, and was thought by her to be a new variant. Six distinct types were recognised in patients on the Atherton Tableland in fifteen months. Antigenic analysis is of great epidemiological importance in these infections, and demands special interest and knowledge, and access to specific diagnostic type antisera.

The importance of this group has been emphasised during the war. Numbers of outbreaks of *Salmonella* infections were reported in civilians: as pointed out in the section on food poisoning, there has also been an increasing incidence among adults during recent years. Draper and others have pointed out the increasing frequency of clinical dysentery, and the seriousness of *Salmonella* infections in infants and young children is

recognised. In treatment no specific was found to be of value in the earlier series. Neither sulphaguanidine nor the soluble sulphonamides affected the course of the disease. The successful treatment of a metastatic pericarditis with penicillin has been mentioned above.

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CHAPTER 6

INFECTIVE HEPATITIS

ONE of the useful lessons of the war has been the revision of current knowledge of epidemic jaundice of the non-leptospiral type. It was expected that the disease now generally known as "infective hepatitis" would be of military importance. Amongst troops on the mainland of Australia leptospiral infections were also expected, even if not in epidemic form, but they did not occur. As in the 1914-1918 war, the familiar civilian type of infectious jaundice caused an appreciable amount of invalidity among forces stationed in the Middle East. The misleading name "catarrhal jaundice" was rather a mental hazard in the understanding of the disease, although in 1939 its nature and its probable identity with jaundice following the parenteral injection of homologous serum were recognised. There has been some confusion in the literature also in a failure to separate this well-defined condition from other infections occasionally associated with jaundice.

During 1939-1945 the Australian Army Medical Services cannot claim to have added substantially to knowledge of the aetiology and epidemiology of the disease, but a considerable body of clinical experience of corroborative value has been accumulated. Fuller scientific information will be found in the medical war histories of Great Britain, New Zealand and United States of America.

Early in the training period of 1940 the A.I.F. in the Middle East encountered epidemic jaundice, and in 1941 the incidence rate was higher. Again in 1942 the 9th Division had a considerable morbidity due to this cause.

CLINICAL FINDINGS

The general clinical picture as seen in the Middle East may now be described. All degrees of severity were encountered, ranging from a low grade in which no clinical jaundice could be detected, to severe types with deep icterus. No deaths occurred. The onset was abrupt with fever and shivering in some; in others it was stealthy. The discovery of jaundice or of bile-stained urine either by doctors or nurses or by the patient himself was often the first event noticed. Even in mild attacks malaise and aching of head, body and limbs were common but not invariable during the latent period before jaundice appeared. Tenderness in the joints rarely occurred. The eyes were injected and congested and sometimes painful on pressure, and the skin of the body was flushed. In a few instances erythematous rashes appeared, and in more severe infections even petechial eruptions. Urticaria was very seldom seen. A fine vesicular enanthem was sometimes seen on the soft palate. Pain in the back was frequent, and in some outbreaks headache was a conspicuous and severe symptom. Neck stiffness was relatively common, with resistance to flexion of the head. Some abdominal symptoms and signs were invariable. Anorexia was a

striking and universal symptom: it was not a mere negative lack of appetite but a positive aversion to food. Nausea and vomiting were frequent, and spontaneous abdominal pain worried most patients. Abdominal tenderness was evident, particularly over the unprotected margin of the liver, which could usually be easily felt. Enlargement of lymph nodes was not very uncommon. Variable degrees of splenic enlargement were reported. Figures are of no real value as they vary so with different observers, but in one collected series in a hospital in Palestine the spleen was reported as palpable in 14 per cent. Renal involvement was unusual except in the rare severe cases. Proteinuria was sometimes observed.

The diagnosis during this stage was not always simple. The sharper onsets suggested sandfly or dengue fever, or the abdominal pain an inflammatory lesion or the early stages of a continued fever, and other conditions such as relapsing fever or mononucleosis were simulated. Such errors might easily persist after jaundice appeared, since this sign may be seen in a number of different infections.

With the onset of jaundice amelioration of symptoms was often striking, especially where the prodromal symptoms were acute. Dark urine might attract attention even before jaundice appeared in the conjunctivae. Urobilin appeared in the urine in the early stages, and often disappeared, reappearing when any obstructive element in the hepatic lesions had resolved, thus allowing reabsorption. The ordinary tests for bile salts and bile pigment were not found of great value, as mere inspection of the urine was often enough. The degree of jaundice varied from case to case and also during the course of many of these illnesses. It was usually moderate, attained its maximum in a week or a day or two less, and disappeared after an extremely variable time, which might extend from a week or two to several months. Except for lethargy and also some rigidity of the neck in the early stages, no signs or symptoms of involvement of the nervous system were observed in this series. It may be observed that in the present state of our knowledge of virus diseases it is not always possible to be sure whether, say, encephalitis or polyneuritis seen in a jaundiced patient is due to the same cause as the jaundice or where the primary affection arises.

No collected observations were made in this series of the blood chemistry or of liver function tests. Other clinical accompaniments of icterus were rare: the stools were seldom pale for more than a short period, and itching of the skin was unusual. Jaundice lasted on the average between two or three weeks, but the patient was usually convalescent before the skin was clear. Very deep degrees of jaundice were sometimes seen.

The anicteric group was small, but the disease was quite recognisable, though of mild type. Occasionally a patient who had had urobilin in the urine and a raised bilirubin content of the blood but no clinical jaundice would require a convalescence comparable with that of others.

The mental phenomena may be mentioned. In the early stages of the illness of febrile patients the state was one of misery for a few days, and depression was often noticed during the later stages, and in convalescence.

Loss of weight was often considerable: this was partly due to the anorexia, but not entirely, and some patients were slow to regain what they had lost.

The questions of relapse and convalescence were important. Recrudescences were not uncommon, and appeared to be an exaggeration of the fluctuating state not uncommonly seen in these patients while jaundiced. A patient might be doing well and quickly show a deepening of jaundice, which usually initiated a longer and more intense illness than the original. Relapses after a more or less brief period also occurred: these were often more severe than the original illness. Relapse or recrudescence was favoured by over-exertion and also by alcohol. It was most important to give each man enough time to regain reasonable health. Pain or tenderness over the liver was a sign for caution in convalescence. The time wastage from this disease was considerable.

Sequelae were unusual. Some of the more serious ones will be described presently. Megalocytic anaemia was occasionally encountered in the Middle East. Bonnin has described a typical severe case, in which prolonged fever, splenomegaly, and deep jaundice of greenish tinge persisted for over four months, yielding finally to transfusions and liver therapy.

During 1940 the incidence rate was not so high as during 1941, probably owing to greater chances of infection in 1941 under action conditions, where sources of the infective agent were probably more numerous and where hygiene was less easily controlled.

Though it was not possible to pursue any investigation other than in the clinical field, assistance was given by arrangement to Major Cameron, R.A.M.C., who carried out research on hepatitis for British forces in the Middle East. During 1941 study of the incidence in the A.I.F. in various sectors and in different seasons showed some interesting features, illustrated in the accompanying table:

1941	Monthly rates of incidence per 1,000 strength in Palestine	in Syria
July	0.31	1.4
August	1.35	3.9
September	2.19	9.48
October	1.92	10.7
November	1.24	8.86
December	0.63	4.66

The late summer and autumn produced more hepatitis than other seasons. Sharp contrast is seen in this table between the seasonal rise in Palestine, a training and reinforcement area, and in Syria, an area of occupation following the campaign. In Syria epidemic conditions produced a peak in the rate far above that of any other area. Later sampling of the figures for the Australian forces in the Middle East showed a striking similarity in the general rates for 1941 and 1942; in both the curve began to climb in the latter part of the summer, and began to subside early in November. Slight differences in peak periods were due to troop movements.

The total yearly rates per 1,000 strength for the A.I.F. in various areas in 1941 are also of interest:

A.I.F. in Palestine	11.51	per	1,000
A.I.F. in Egypt (including Tobruk)	22.07	„	„
A.I.F. in Syria	43.85	„	„
Total for A.I.F.	28.18	„	„

With these figures may be compared the incidence rate for the 9th Division in 1942; during the period of the operations at El Alamein the yearly rate was 36 per 1,000.

Special mention may be made of jaundice in the closed community of besieged Tobruk; an increase became evident there in August 1941, and by the end of September a large proportion of cases of medical illness was due to jaundice. A feature of this outbreak was the high proportion of toxic infections with high fever.

The question of convalescence has been mentioned. In Syria where the numbers were heaviest, and where Australian casualty clearing stations and field ambulances were filling the role of hospitals, hepatitis was rather a problem. Men with mild infections, as judged by light grades of jaundice, were held in clearing stations, but it was found that patients sent on to the corps rest station in Syria were often jaundiced for three or four weeks, and the A.D.M.S. of the 7th Division found it desirable to send as many men as possible to hospitals in Palestine, whence they went to a convalescent depot.

Hepatitis occurred in the 8th Division in Malaya also, and up to the time of the capitulation was of mild or average severity. During the subsequent periods the disease kept recurring in working camps and in fixed camp hospitals. Medical officers thought that there was an undue proportion of severe attacks. Whether there was any greater innate epidemic severity is uncertain, but it seems more likely that the poor nutritional state of the men was an important factor. Their diet was dangerously low in good protein and the vitamin *B* complex. It is not sure if all the hepatitis encountered in Burma and Thailand was of viral type. A. T. H. Marsden recorded a curious outbreak of a mild febrile disease with a protracted course, anorexia, tenderness of the liver and slight jaundice. This did not closely resemble the usual mild forms of infective hepatitis, and autopsy after death from accidental causes showed periportal fibrosis with cellular infiltration of the portal tracts, the picture rather resembling the necrotic changes seen in experimental cirrhosis. Marsden suggested the possibility of nutritional causes combined with bacterial infection. Till the end of the Japanese war hepatitis continued to appear among the prisoners of war in the South-East Asian Zone.

AETIOLOGY AND EPIDEMIOLOGY

These experiences did not shed much light on the aetiology and epidemiology of the disease. It was observed that increase in the fly population of an area in which hepatitis was rife ran roughly parallel

with increase in incidence of the disease, but the hypothesis of droplet infection, though without any sure foundation, was still rather widely held among medical men. A suggestion was made in Tobruk during the period of high incidence that there was some association between hepatitis and the well water supply. Major Van Rooyen of the 15th Scottish General Hospital in Cairo, from information supplied to him concerning epidemic jaundice in the A.I.F. in 1941, did not find any definite relationship between the peak of hepatitis and that of dysentry. Figures for pneumonia were also examined, but were too small to be significant. Consideration of the clinical findings of hepatitis suggested that about the fourth day a combination of virus with antibody took place as in yellow fever. Colonel Fairley, Consulting Physician A.I.F., in pointing this out remarked that only during the incubation period or the first three or four days of illness should the blood be infectious. This would be of importance only if a blood-bearing vector was concerned or if experimental work was planned. There was nothing to point to the existence of such an insect vector.

In 1942 the 9th Division, like other troops at action stations in the Western Desert, suffered considerably from jaundice. During the quarter ending September 1942 the 2/6th A.G.H. admitted many more men with jaundice than with sandfly fever. The medical units in the field also reported large numbers. Conditions of hygiene were not satisfactory. The occupied areas were fouled, and flies were present in myriads which were difficult to cope with owing to the conditions in the desert, and scarcity of men and materials for the work. The special experience of the New Zealand division here was of great interest and importance. They suffered heavily, and their medical advisers had no doubt of the connection between hepatitis and faecal contamination particularly by flies. The studies of Kirk in the New Zealand division are of special interest. The practical importance of the site occupied by troops, to some extent illustrated by Australian experiences, was underlined in the analysis of the massive outbreaks among British and New Zealand troops facing Rommel in the Western Desert. This aspect is dealt with in the New Zealand Medical War History. When the 9th Division returned to Australia in February, 1943, there was strong epidemiological evidence that hepatitis was a bowel-borne disease. Cameron, Van Rooyen and others had not been able to establish the connection by experimental means, but Havens and co-workers later proved beyond doubt that the virus was not only in the blood but also in the faeces, and could be passed on to human volunteers.

A matter of some interest was whether the disease as occurring in the various sectors of the Middle East was the same in nature. Sampling of nearly 1,000 case-histories of men who had suffered from infective hepatitis in the Middle East showed that, although the usual individual and epidemic differences were evident, there was no essential difference in the clinical picture seen in Palestine, Syria, Egypt and the Western Desert. Sampling of a later series of 500 cases in Western Australia in 1943 gave a similar result. Though there was no doubt whatever of the

identity of this epidemic disease in Australia and overseas, further studies in Australia and the South-West Pacific Area brought to light some points of importance. In Australia some of the outbreaks attained local epidemic proportions. In Alice Springs, for example, an isolated settlement, a mild epidemic prevailed in the early summer of 1942. Attempts were made by Professor Hurst of Adelaide to isolate a virus from this outbreak, but without success.

In Western Australia there was also an epidemic about this time, in which early severe headache was a constant and dominant feature. Early in 1943 an outbreak occurred in the 1st Australian Armoured Division. No special connection could be established between this and alimentary tract infection, but it may be noted that outbreaks of dysentery had taken place in the same area.

In the Northern Territory cases of jaundice had been occurring among servicemen, but in August 1942, an outbreak occurred which aroused considerable attention as the possibility was at first entertained of the jaundice being due to leptospirosis. Eighteen men were admitted to the 121st A.G.H. at Katherine with jaundice. Of these six were diagnosed as having infective hepatitis. In the remainder spirochaetes were reported in blood smears under darkground illumination. Six of these men were only mildly ill, five had a rash, erythematous, macular or petechial in nature. Lymph glands were palpable in a few. Headache and anorexia were common symptoms. Agglutination tests were carried out in Sydney for leptospiral infection, but no reaction was obtained, and guinea pig inoculations were likewise negative. Similar cases were found at Adelaide River at the 119th A.G.H. Major I. M. Mackerras investigated these patients but found that the bodies seen on the dark ground were artefacts, such as described by Wenyon and others. There was no doubt that the infection was epidemic hepatitis and not leptospirosis. On several other occasions such artefacts, due to molecular movement of inert material, were found in the blood of men with malaria or no declared disease. Full investigation was made of all the patients in this series, from the epidemiological point of view, but no useful information was gathered, except that on all grounds these infections were characteristic of epidemic hepatitis and not of leptospiral infection. It may be mentioned too that there was a high incidence of jaundice at the time among American servicemen in the area.

HOMOLOGOUS SERUM JAUNDICE

This last observation was of possible significance in connection with homologous serum jaundice, instances of which were occurring in Australia, also among American servicemen and women. These were due to yellow fever inoculations, which thus entered the historical stage once again, after having agitated the scientific world several times during preceding years. The facts about these outbreaks are well recorded in the literature, and general agreement had been reached that they were due to a virus infection, similar or identical with that causing infective hepatitis. The extreme viability of the virus and its ready communicability by small

quantities of material explained its capacity to cause jaundice after inoculation into the blood stream. It is now common knowledge how transfusion of blood or pooled serum may transmit the infection, even by such small amounts as were present in some batches of yellow fever vaccine, or even by the incredibly small traces conveyed by syringes or needles used for vene-puncture for purposes of diagnosis or treatment.

But at first, when severe febrile forms of hepatitis occurred in Allied soldiers after reaching Australia, some concern was felt until their real nature was disclosed. The extraordinarily long incubation period that characterises homologous serum jaundice introduces a difficulty in diagnosis till the full history is known, and even now it is difficult to explain except by certain postulates about some differing nature of the virus. One minor point of interest was that of sex incidence. A rumor was current that inoculation jaundice was observed only in men: this was obviously untrue, and was simply refuted when American nurses were admitted to Australian hospitals during the early part of 1942 suffering from this complaint.

The greater average severity of inoculation jaundice was noted, and though there is no evidence that this form of infection can be transmitted to others in the same ways as ordinary epidemic hepatitis, it was observed that more severe infections due to the epidemic disease were also occurring in Australia. Several deaths occurred among Australian servicemen from severe forms of infective hepatitis. The history of these was quite distinct from that of the subacute atrophy of the liver due to toxic causes, though the clinical end state was the same.

Towards the end of the Japanese war, Stuckey reported a case of very severe hepatitis with the uncommon sequels of massive effusions and oedema, due no doubt to the osmotic disturbances caused by an altered ratio of globulin and albumin in the blood. This patient eventually recovered.

Severe haemorrhagic complications were also seen, not always among patients otherwise seriously ill. It is possible that some deficiency of vitamin *K* was responsible. Massive intestinal bleeding took place in one young man who recovered, and a fatal result occurred in the case of another who had severe intra-abdominal haemorrhage. The rapid downhill course of patients dying of cholaemia due to hepatic necrosis is well known. This occurred in one man who had an unexpected relapse when apparently recovering from a jaundice of only moderate severity. This man suffered a severe vasovagal collapse less than twenty-four hours before his death, a phenomenon also noted as a terminal event in fatal jaundice of the homologous serum type. Autopsy showed the findings characteristic of subacute atrophy of the liver.

No figures can be given of the incidence in the Services of jaundice following transfusion of blood or serum. The possibility of a complete follow-up was considered more than once, but with facilities available there were difficulties, owing to the wide areas concerned, the dispersal and movement of troops, and the long period of observation necessary. Medical men and women closely associated with blood transfusion services

have in general found that homologous serum hepatitis has appeared in only a very small percentage of persons who had previously received pooled serum. The long incubation period, ranging from 40 to 160 days, has no doubt made the disease appear rarer than it is, but the risk in Australia during the war years seems to have been remote. Further details are given in the section on blood transfusion.

OTHER FEATURES

The incidence rates of hepatitis in the Australian Army on the mainland were low, and an interesting contrast is seen with the figures for Australian soldiers in the South-West Pacific Area.

Monthly Rates per 1,000 for infective hepatitis

	1942	1943	1944	1945
Australia . .	0.15	1.81	0.63	0.56
S.W.P.A. .	0.51	3.93	9.25	3.53

In Australia several minor outbreaks were observed in restricted areas. In one such epidemic at Innisfail in Northern Queensland, over forty patients with mild jaundice were admitted to hospital from one infantry battalion. Flies were prevalent in the unit lines, and the medical officer pointed out that the same cup was used by the members of one company at atebrin parades. A number of patients whose symptoms were suspicious, though they were not at the time jaundiced, were isolated. The wisdom of this was justified by the later appearance of jaundice in these men. Other hygienic faults were remedied and no more cases occurred.

In the late part of 1944 and early part of 1945 hepatitis was reported from the Atherton Tableland. These infections were mild, though the period of convalescence averaged six weeks. Interchange of men between this rest and training area and the forward zones in New Guinea explained such outbreaks. In the islands to the north the higher incidence was probably a reflection of less rigid hygiene in forward areas, and the aggregation of the men in the jungle into smaller community units.

During the latter part of 1942 and the early part of 1943 most of the hepatitis in New Guinea came from the forward areas, and though the total numbers were not large, many men were admitted to the 2/9th A.G.H. and the 5th C.C.S. in the upper Moresby area with jaundice. This presented an important problem in diagnosis, for it was often not easy to differentiate between infective hepatitis and toxic malarial jaundice. Owing to the trying conditions in the combat areas and great difficulties in evacuation of the sick, delays often occurred in bringing patients under treatment. Suppressive drugs were not always taken in efficient dosage, and some men were untreated or self-treated before arrival in hospital. Most of the men were exhausted and suffered from impaired nutrition. Malignant tertian malaria appeared in most of its serious manifestations, such as toxic hyper-infective states, cerebral malaria, blackwater fever and bilious remittent fever. This has been mentioned in the section dealing with malaria.

Men with jaundice were observed to come from both malarious and non-malarious areas. The latter were considered possibly to have epidemic jaundice, but not much reliance could be placed on the usual diagnostic features. The general clinical condition of these tired men was not very helpful in diagnosis, nor was the absence or presence of parasites in the blood, nor the depth of the jaundice. In a series of over seventy men definitely diagnosed as suffering from infective hepatitis the stools were usually clay coloured for a brief period, then bile disappeared from the urine and urobilin reappeared as intestinal absorption was resumed. The bilirubin content of the serum was not of much discriminative value: it was usually higher in infective hepatitis, and reached as high a level as 29 milligrammes per cent in this series, whereas in malarial jaundice the highest reading was 16 milligrammes.

The seriousness of jaundice as a sign of toxic malaria was emphasised by the occurrence of several deaths of very ill men soon after admission. At post-mortem examination the liver was of a slaty grey colour, showed toxic degeneration and contained many malarial parasites. With early energetic treatment a number of men recovered from such attacks, and the policy was wisely followed of treating on that assumption all men who might have a toxic malarial hepatitis. A jaundiced man coming from a hyper-endemic area, or with *P. falciparum* in the blood was treated with intravenously administered quinine without delay. Possibly this practice was over cautious at times, but it was wise, and followed the procedure laid down in the Australian services for the treatment of severe malaria.

In other parts of the South-West Pacific Area where Australian troops fought, the incidence of hepatitis, as shown above, was considerable. Except for the occurrence of an occasional severe or dangerous attack, no special features were observed. In the early part of 1945 it was noticed at Madang that most men with hepatitis suffered from mental depression. This is of course not an uncommon feature of the disease, but in this instance headache and lethargy during convalescence were prominent symptoms, and it is recorded that a good deal of encouragement was necessary to rehabilitate the men.

TREATMENT

No special advances can be recorded. At first a diet of a low fat content was used, with corresponding increase in carbohydrates. Later, following the current teaching, a diet with a relatively high protein content was allowed. Perhaps some control of the usual loss of weight was achieved, but no special observations were made. Later, in New Guinea, an experiment in therapy was carried out in the 2/1st A.G.H. Every alternate patient was treated with 10 units of insulin twice a day, with 5 ounces of glucose and 75 milligrammes of ascorbic acid for 10 days. Observations were made every third day of the excretion of bile constituents, particularly urobilinogen and urobilin. The disappearance of pigment and its later appearance were found to be significant. The average period of jaundice in 25 treated patients was 17.6 days (ranging from 11-26) while

the controls ranged from 11 to 31 and averaged 22.4 days, 6 periods being over 26 days.

With regard to other routine indications for treatment, as already indicated, observation of the blood state was desirable in severe attacks, and undue and premature exertion or strain in convalescence was avoided.

PROPHYLAXIS

Field experiences during the later campaigns in the Middle East revealed the true nature of infective hepatitis as a bowel-borne disease, and experimental proof finally clinched this. The need for further precautions in hospitals was then raised, and though there was some opposition at first from those who thought it unnecessary, greater care in segregation was taken. In the northern parts of Australia the practical value of such measures was shown by the control of local outbreaks, such as mentioned above, and in the forward island areas patients with hepatitis were handled with the same precautions as those with dysentery. They were housed in separate wards, which were protected by fly wire as this became available.

During the war the epidemiological outlook on infective hepatitis has completely changed, it is surely now a controllable disease.

FURTHER RESEARCH

The subject of research done since the war cannot be dealt with here, but it may be pointed out that experience of hepatitis during the war years has advanced the pathological knowledge of the disease. At the Walter and Eliza Hall Institute in particular, a number of workers (King, Wood and others) have contributed to the living pathology of the disease. In addition, the diffusion of knowledge gained throughout the war years must be of great advantage to a large number of medical officers.

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(*b*) *Vector-borne Group*

CHAPTER 7

MALARIA

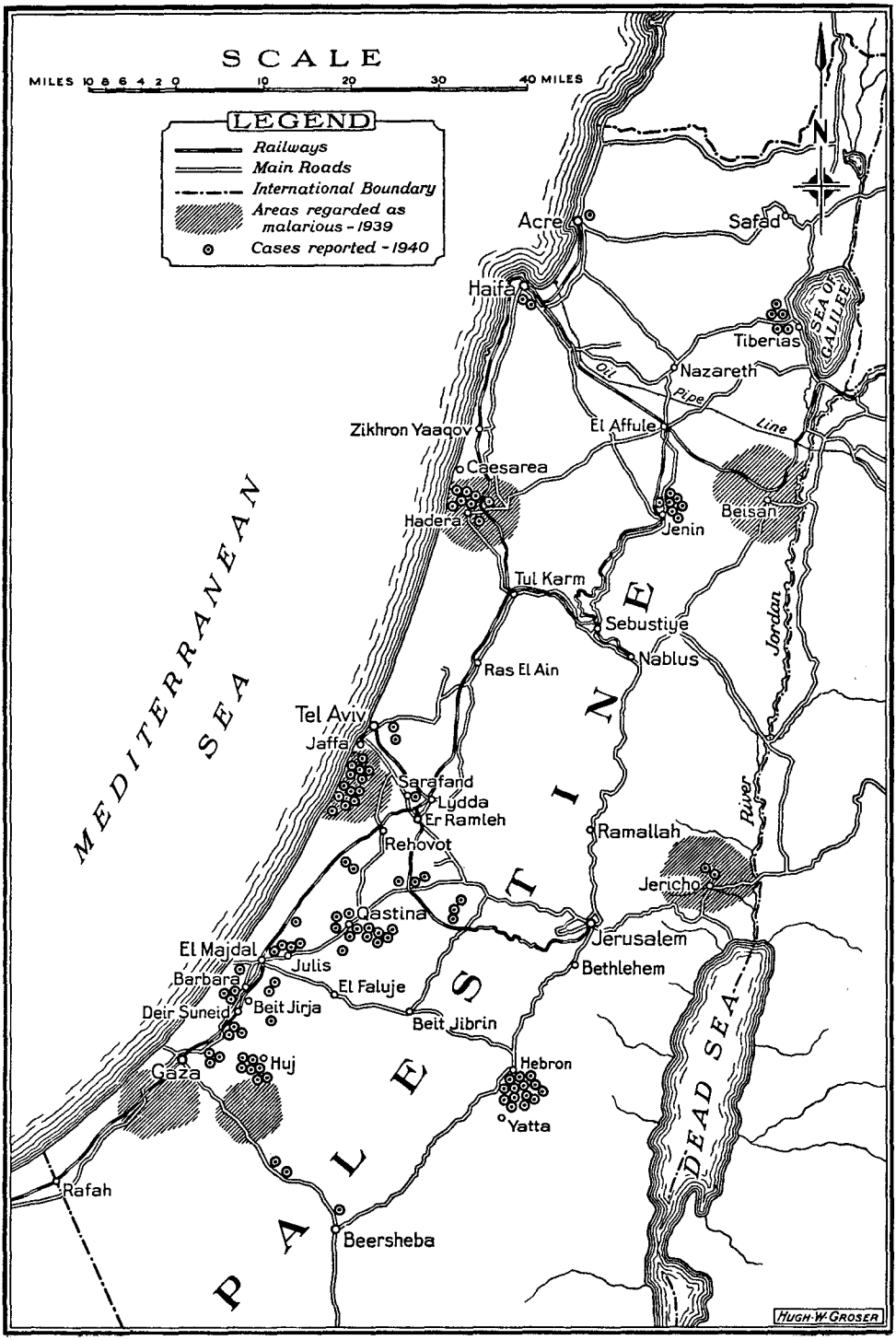
FROM the beginning of the 1939-1945 war till its end malaria was an important problem to the Australian forces.

MALARIA IN PALESTINE

When troops arrived in Palestine in February 1940 malarial control was good in the region of their camp sites, and here the risk was virtually nil, but there were areas known to be potentially dangerous, especially towards the northern border. Beyond this lay Syria, then held by the French, and known to be malarious. During 1940 there were 131 A.I.F. patients with malaria admitted to hospital from an average strength of 14,000 men in Palestine. Curiously, the first Australian soldier treated for malaria had a recurrence of a previous infection acquired in New Guinea. Most of the local infections came from suspected areas; some like Hadera in the north were known to be incompletely controlled, others, like the area south of Jaffa, were thought to be under control.

As the summer came on field hygiene sections reported finding anophelines breeding in additional areas. Some of these were in wadis near Arab settlements; most of them were adjacent to camps. In settled areas civil control was good, but it was soon evident that even troops in training might contract malaria, usually when on night manoeuvres. The incidence was undoubtedly small, but it was clear that active service conditions in areas not so well-controlled would tell a different story. Even so, it was not easy to prevent combatant units from using infected areas for night training exercises, and even in some camp areas mosquito breeding was occurring.

The vector mosquitoes for Palestine and Syria were *Anopheles elutus* and *superpictus,* and when later in the year Australian troops moved to Egypt other vectors were encountered, chiefly *A. pharoensis.* During the latter part of 1940 at the instance of Colonel M. J. Holmes, Director of Hygiene and Pathology, an attempt was made by the army medical services in Australia to have an entomologist appointed, chiefly to train a number of non-commissioned officers and for the nucleus of an entomological service. Unfortunately this far-sighted suggestion was not approved by the Adjutant-General. Later in the summer of 1940 instructions were issued that no camps should be sited within a mile of a village and none within two miles if over 20 per cent of the children were infected. Swamps were to be avoided, and due consideration given to the direction of prevailing winds. An excellent illustration of the difference in the malarial risk under military conditions as contrasted with the civil risk was given in the Wadi



Palestine: malarious areas.

Ghazza and surrounding areas. These were regarded as efficiently controlled from Hebron in the east to Rafah in the south, and no cases of malaria had been reported for three years, yet nearly one-fourth of the men who contracted malaria in 1940 had been infected while training in that area. At this time only limited equipment for personal protection was available; in fact anti-malarial measures were mainly confined to the avoidance of dangerous areas and the control of breeding in the vicinity of camps.

No general order was made at this time with regard to suppression. Quinine, 5 grains a day, was the recognised dosage in circumstances requiring the use of a suppressive drug; this could be increased to 10 grains if the conditions of transmission made it necessary in order to keep infections below the clinical level. In the treatment of clinical malaria in these early days an attempt was made to differentiate between the methods used for malignant and benign tertian infections. Plasmoquine was then in rather restricted supply and it was chiefly used for its gametocidal action on the crescents of the *falciparum* parasite, as there seemed better prospects of preventing relapses or recrudescences in this dangerous type than in benign tertian. Follow-up courses of quinine were also used with the same end in view. Benign tertian was chiefly treated with quinine and atebrin.[1]

It was, however, evident that a standard course of treatment for all types of malaria was desirable, and this was adopted, quinine, atebrin and plasmoquine in sequence being used. The routine was as follows: Quinine 10 grains 3 times daily for 3 days; atebrin 0.1 gramme 3 times daily for 5 days; and after an interval of 1 to 2 days, plasmoquine 0.01 gramme 3 times a day for 3 days, or 5 days preferably if supplies permitted. It was thought at that time that plasmoquine was more likely to have a toxic effect if it followed without break after atebrin. The dosage of plasmoquine was reckoned in terms of plasmoquine base. This treatment was based on extensive Indian experience, and was believed to offer the best chance of minimising relapses in all types.

MALARIA IN GREECE AND CRETE

In January 1941 the 6th Australian Division was engaged in the first Libyan campaign, in which malaria was not a significant medical problem. At this time the British offer of assistance to Greece made it probable that forces would be committed to a campaign in South-East Europe. Accordingly an appreciation of the malarial situation in that region was prepared by Colonels N. H. Fairley[2] and J. S. K. Boyd.[3] In this they pointed out that troops operating in Greece, Macedonia and the Balkans from June to

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[1] The term "Atebrin" is used throughout without distinction of its source. Whether referring to the original patent "Atebrin" produced in Germany, or the British "Mepacrine" or the American "Atabrine" the word atebrin came to be used in all Australian communications, and in this sense it will here be used, embracing the original and all identical or equivalent drugs.
Similarly, "Plasmoquine" includes all forms and substitutes of this drug, such as "Pamoquin".

[2] Consulting Physician to A.I.F. in M.E. and temporarily Consultant in Tropical Diseases to British Forces in M.E.

[3] Deputy Director of Pathology, British Forces in M.E.

September would face the hazard of a crippling incidence of malaria. Despite advances in therapeutic and preventive methods, they stressed the danger of non-immune troops being manoeuvred into some of the most malarious country in the world, where anti-larval measures had little chance of success. General Wavell, Commander-in-Chief, Middle East, was at first reluctant to accept the strategic limitations imposed by what seemed to him to be an unduly pessimistic opinion, but when all the facts were placed before him agreed that the malarial risks in these areas must be taken into consideration in all forward planning.

Early medical planning was undertaken at once. In March, 1941, when the 6th Australian Division, and, as at first believed, the 7th Division also, were committed to a campaign in Greece they were warned that preparations for anti-larval measures must be initiated at once, and anti-malarial stores obtained, including nets, repellent cream and drugs. Surveys were made by the British Force, the dangerous areas were noted, and labour was supplied for control work. From the beginning of April mosquitoes were beginning to bite, even up to the snow line, though only an occasional case of malaria was expected till the middle of April at the earliest. In the brief period before the Germans entered Yugoslavia as much was done as possible, but events moved with such speed that the end of this ill-starred episode was in sight before either men or material had been assembled. The plans to combat malaria were therefore never put to a test, as Greece was evacuated at the end of April. One unfortunate result of the forced abandonment of equipment was the loss of 60,000 mosquito nets. During the defence of Crete concern was felt by the medical units caring for troops on the island about the malarial risks in the summer. Conditions and meagre supplies offered little scope for purposeful action, but malarious areas were mapped out, and precautions enjoined in instructions. One such instruction laid down that "suppressive" quinine should be given in infected areas from the 1st June. However, at the beginning of June the campaign had ended with the evacuation of Crete. The incidence of malaria among the men who returned was negligible.

ANTI-MALARIAL MEASURES

Meanwhile anti-malarial training had been steadily pursued in Palestine and Egypt. Indeed from early in 1940 this had been organised in schools which used the resources of British and Australian services, and of the civil health administrations and with the help of the staff of the Hebrew University of Jerusalem. Didactic instruction was supplemented by work in the field. In April 1941, the possible importance of events in Greece on the military practice of preventive medicine emphasised the need for an authoritative account of malaria for the use of all medical officers. Arrangements were made for this to be compiled by Colonels Fairley and Boyd.

The publication of this account in June 1941 consolidated previous directions, and provided what was really a comprehensive though condensed textbook. Its scope and contents may now be briefly recounted, since they represent the basis of knowledge and standard of practice

adopted by the Australian medical services in the Middle East in 1941 From the clinical aspect its teachings laid the foundation of the highly successful handling of the many thousands of men who were later treated in Australian medical units for malaria.

The only varieties of malarial parasite of military importance in the Middle East were *Plasmodium falciparum* and *P. vivax,* producing malignant tertian and benign tertian fevers respectively. *P. malariae,* causing quartan fever was rare, and *P. ovale* was not seen in the Middle East. The life history and morphology of all the types were described in detail. The habits of the important local vector mosquitoes were described. *Anopheles elutus* bred well in valleys and in coastal swamps in brackish water, and *A. superpictus* in rocky hill streams or water near springs, while *A. claviger* (*bifurcatus*), seen mainly in North Palestine and Syria, was chiefly a house dweller and bred in wells and underground cisterns. *A. pharoensis,* the chief vector in Egypt, bred in swamps and rice fields, mainly in the delta and oases. The seasonal importance of malaria in the Middle East was emphasised. From May till October both M.T. and B.T.[4] were transmitted, but the peak of B.T. transmission was reached in the early summer, and that of M.T. in the later months. M.T. though not subject to the repeated relapses which are characteristic of B.T. sometimes produced recrudescences after a period of some six weeks. With the strains of B.T. met in the Middle East relapse was not usually manifest until after some months, often up to eight or nine months.

Full descriptions were given of primary and recurrent attacks and stress was laid on the fallacy of expecting a regular periodicity to be an early feature of malarial fever. Particular attention was paid to the varied manifestations of malignant malaria, such as hyperpyrexia, cerebral malaria with production of coma or simulation of other nervous diseases, algid malaria, producing the picture of severe shock, malaria imitating diseases of other systems, and the purpuric type. Special mention was made of the importance of M.T. as a cause of symptoms suggesting acute abdominal emergencies. The significance of anaemia, sometimes of severe grade and of jaundice in M.T. was pointed out. Diagnostic methods were described in detail; thick films were universally used, thin films only being used to verify plasmodial types. Facilities for the necessary laboratory procedures were available in all field medical units, whose physicians were competent to make a microscopic diagnosis. Giemsa and Leishman's strains were supplied and chiefly used. Field's method aroused interest about this time; extended experience in other areas later showed its value as a technique both rapid and reliable.

The chief considerations in making a diagnosis were listed as follows:

(1) blood examination for parasites, mononuclear cells, pigmented leucocytes and persistent leucopenia;

[4] The abbreviations M.T. and B.T. for malignant tertian and benign tertian malaria respectively will be used. The term "subtertian" for M.T. was used for a time in an endeavour to obviate the rather alarming implication in the name, but "malignant" tertian was too firmly established and became the official designation.

(2) the history of the patient, with special reference to periodic fever;
(3) demonstrable enlargement of the spleen and often of the liver;
(4) evidences of blood destruction, such as anaemia, jaundice and urobilinuria;
(5) the therapeutic test.

The standard treatment already mentioned was laid down in this memorandum as the official method. Intravenous administration of quinine hydrochloride was the rule whenever the patient could not swallow or retain quinine, or when absorption of the drug was in question, and in all severe or dangerous forms of illness due to malaria. Hyperinfection was included in the latter category; this was defined as an infection in which over 4 per cent of red cells were parasitised, or over 5 per cent of the infected cells carried multiple parasites, or in which pigmented asexual forms were present. Intravenous use of quinine was almost confined to the treatment of M.T., and with a safe dilution of the drug (one grain to one millilitre) and slow injection (two millilitres per minute) toxic effects were negligible. Intramuscular injection of quinine was very seldom used owing to the possibility of discomfort and necrosis of muscle. Atebrin was occasionally used for intramuscular injection, but where rapid action was required the intravenous use of quinine was pre-eminent.

Quinine was prescribed for suppressive treatment, but it was pointed out that even 10 grains a day could not do more than render an infection sub-clinical, and that the dose was better to be lower than this amount unless conditions in a hyperendemic area made it necessary. Stress was laid on the solubility of quinine, and where a mixture could not be given and tablets were used, only a soluble salt such is bihydrochloride, bisulphate or hydrochloride was advised. Special care was enjoined for wounded patients in a hyperendemic area. Therefore it was advised that quinine be given for fourteen days in suppressive doses of 10 grains daily or atebrin 0.3 gramme the first day and twice a week thereafter. Where blood transfusion was necessary and a donor was used who had been exposed to the risk of malaria, the donor received 10 grains of quinine or 0.2 gramme of atebrin six to twelve hours before his blood was collected if this was possible. The recipient was given 0.2 gramme of atebrin at once by mouth, or 10 grains of quinine by mouth or intravenous drip. If the donor was in fact found to be suffering from malaria a standard course was given to the patient at once. In all cases a follow-up course of 10 grains of quinine a day or 0.3 gramme of atebrin in divided doses, twice weekly, was ordered for two weeks.

This comprehensive brochure proved to be of great value, not only in the Middle East, but also in later operations. An official pamphlet on "The Prevention of Malaria" was also prepared and distributed for the information of all officers, combatant and medical alike.

MALARIA IN SYRIA

Meanwhile important events were occurring in other parts of the Middle East. While the brief Grecian campaign was hastening on, German infiltra-

tion was proceeding into Syria; this made it necessary to prepare a force for occupation. The division of France introduced peculiar political and military difficulties into this venture, which was undertaken following severe losses of men and material, and during the simultaneous pursuance of campaigns in other areas of the Middle East. The assembly and equipment of an adequate force were at the time not easy; supplies were taken straight from ships for the new force which comprised British, Australian, Indian and Free French troops. Though anti-malarial equipment was gathered for the force, there was no consultation with malariologists beforehand. On the eve of the entry into Syria a conference of medical leaders and malaria experts was held and a quick survey of Northern Palestine made, but these could not make good the lack of consultation in the beginning. Intelligence from Syria was sketchy; information about the medical conditions was limited and often unreliable, but it was known that the malarial hazard was considerable.

When the combined forces entered Syria on 8th June 1941, the malarial season was just beginning. Many of the troops, including the Australians, had not previously been exposed to malaria, and in addition were unacquainted with the risks of the country they were about to enter. Great efforts were made to educate all ranks in this respect, but it cannot be said that the troops entering Syria were "malaria-conscious". Some of the equipment was inadequate in quantity, such as the nets, which were also often ineffective in type. Nets from India to replace those lost in Greece went astray and were not available at the time when they were most wanted. The need of precautionary measures was felt before the campaign actually began, for even one night spent thus in the neighbourhood of the highly malarious Hula marshes, just south of the border between Syria and Palestine, constituted a definite risk.

Repellent cream was used: it was issued in bulk and distributed with some difficulty. Many of the troops did not have protective clothing. Quinine supplies were deficient at first, but its issue through the Army Service Corps with rations simplified distribution. The 7th Australian Division lacked some equipment, such as nets, but other protective measures were available, though their use was difficult to enforce. Even responsible officers sometimes showed a bad example by wearing unsuitable clothing after dark and in neglecting to take quinine. An Australian air force squadron in a malarious area in North Palestine had no nets, and no long-sleeved shirts were on issue.

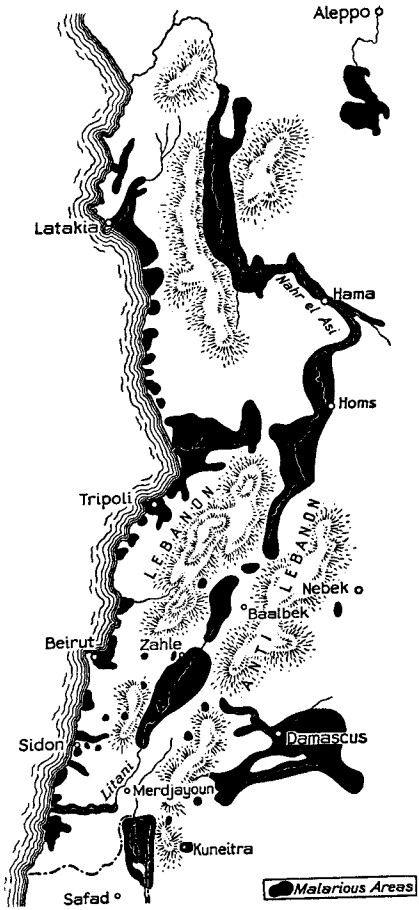
It was soon evident that malaria was occurring among the advancing troops. Malignant malaria appeared towards the end of June with a definite proportion of severe infections, and it was expected to assume epidemic proportions by August if prevailing conditions continued. Fortunately the brief but arduous campaign was over by the middle of July, but during the phase of action in Syria the casualties due to sickness had exceeded battle casualties and most of these were due to malaria. In the first month 500 patients with proved infections were admitted to two hospitals in Palestine, and the rush of malarial casualties was responsible for a good

proportion of the hospital expansion which was necessary during this campaign. The training of nurses in the taking of thick films from every man with a wound or with a rise in temperature was found essential. Then and in later years this was found a great aid to rapid diagnosis. In the Middle East it was found advisable to protect these slides from flies which quickly devoured the dry blood films.

It is hard to estimate just what effect the anti-malarial measures had on the incidence of malaria during the actual period of fighting. The ratio of B.T. to M.T. was about 4 to 1. This was expected, but when hostilities ceased in Syria the M.T. rate was rising. There were indications then that the troops were faced with the upsweeping curve of a typical epidemic of M.T. Without belittling the efforts of all concerned in anti-malarial measures, and the cooperation of military formations, we can attribute the improvement in the position as due rather to the cessation of hostilities, which allowed an accurate mosquito survey of the country and permitted stationing of troops in safer areas. All camp areas were then supervised and precautions tightened. Further, a dry summer hindered mosquito breeding, and transmission was not heavy enough to cause an epidemic, but a war of movement during the period August to October would have caused heavy malarial losses. As it was, from the entry of troops into Syria to the beginning of September 1,400 cases of malaria were reported to the I Australian Corps; the total of cases for the A.I.F. in the Middle East during 1941 was recorded as 2,331. The actual number of infections was greater than this. After their return to Australia many relapses were seen in men of the 7th Division whose primary attack had been suppressed, not observed, or mistaken for some other febrile condition. Early and unwarranted optimism as to complete cure of B.T. in Syria was shattered by this experience. The experience of individual units indicated heavy infection in bad areas: one brigade had 350 cases in 16 days without reckoning those suppressed by quinine. At first 5 grains of quinine daily was used as a suppressive dose, and later 10 grains. In September suppression was gradually stopped. The intensification of control measures in July was of course of great value. It was felt to be urgent at the time because there were grounds for suspecting a German attack from the north within a few months. Though skilled malariological work in Syria had been lacking before 1941, this was made good by the combined efforts of British and Australian experts. In July, on the advice of the British consulting malariologist, Colonel J. A. Sinton, the principle was accepted that camps should be only sited in safe areas. Night movements were reduced to a minimum. Vigorous propaganda was pursued by lectures and posters. In August long trousers and long sleeved shirts were issued, and orders concerning clothing, the use of nets and repellent cream, and controlling bivouac areas were laid down by the I Australian Corps.

The topographical problem in Syria was varied. The country was divided by two mountain ranges, the Lebanon and Anti-Lebanon Ranges, between which was a heavily cultivated plateau with streams and swamps. Coastwise was a narrow strip densely occupied and intensively tilled, while

in the interior lay the plains with slower running streams, and still farther eastward the desert. The vector mosquitoes were, as expected, *A. elutus,* and *A. superpictus,* and in habitations with wells and cisterns, *A. bifurcatus.* In July transmission of B.T. by *elutus* was lessening, but M.T. transmission was increasing. This mosquito was highly dangerous: it bred in swamps and still water, especially with floating vegetation, and had a long range of dispersal, three or four miles or even twice as far late in the season. *A. superpictus* was also a dangerous vector, breeding readily in hill streams at the edges or in pools. It was most prevalent in late summer and autumn, and had a range of two miles.



Syria: malarious areas.

Anti-larval measures included the oiling and dusting of breeding grounds with Paris green, and the canalising of streams so as to abolish breeding grounds. Anti-malarial control units were formed for the first time in the

Australian Army, and these and labour squads carried out numbers of extensive engineering feats with their own resources. Adult mosquitoes were attacked by sprays in dwellings and biting was reduced by the use of nets and repellent cream. Extensive surveys were made and much information collected as to the habits of vectors and infection rates of native populations.

Though malaria continued, the dry weather, good camp siting and energetic measures abated its incidence, and the winter came in Syria without serious trouble. The chief lesson of the Syrian campaign was the necessity of early planning, so that education of all ranks in malarial risks and anti-malarial discipline should be carried out, supplies obtained and even during a period of action preventive measures carried out as fully as military conditions permit. The organisation of malaria control was at first extemporised, but later made highly efficient. Its success emphasised the paramount need for the presence of scientific advisers who could apply the information gained on the spot. Syria showed too what malariologists know well, that only minute regional study of the conditions can make control effective; generalisations about such matters as the breeding or biting habits of mosquitoes, for example, are often dangerously misleading.

During the winter of 1941 and the first half of 1942 Northern Syria was held as a fortress area, and when summer came malaria returned. Even while the weather was still cold it was necessary to spray villages to kill hibernating mosquitoes. In the hot weather breeding was profuse. Atebrin was introduced as a suppressive, the dose being 0.2 gramme twice weekly. The movement of troops increased the risk perceptibly, and occasionally combatant units disregarded warnings about unsafe bivouac areas and other dangers and paid the penalty in malaria. In one battalion 315 men were exposed to the risk of infection in a highly malarious area near the Syrian border. Shortly afterwards this unit was transferred to Egypt, and through an error the dose of suppressive atebrin was halved. One hundred and sixty-three of these men needed treatment for febrile illness at first thought to be sandfly fever, but 46 were soon proved to be suffering from malaria and further investigation showed that the number with malaria was over 120. It is interesting to note that even when the full suppressive dosage of atebrin was restored (then only 0.4 gramme a week) it was insufficient to prevent overt infection.

IN THE MIDDLE EAST IN 1942

In Egypt before and during the Alamein battle, the general incidence of malaria was inconsiderable. Late in July sudden plagues of *Anopheles pharoensis* visited the Alamein region, but no outbreaks of malaria followed. These were thought to be due to air currents from the breeding areas in the Nile Delta. Dissection showed that the mosquitoes were poor vectors, and the absence of infection amongst those visited by the plague was correctly forecast by the malariologists. The return of the 9th Division to Australia ended the association of the A.I.F. with the Middle East.

During this period there were 131 cases of reported malaria in 1940, 2,331 in 1941 and 934 in 1942.

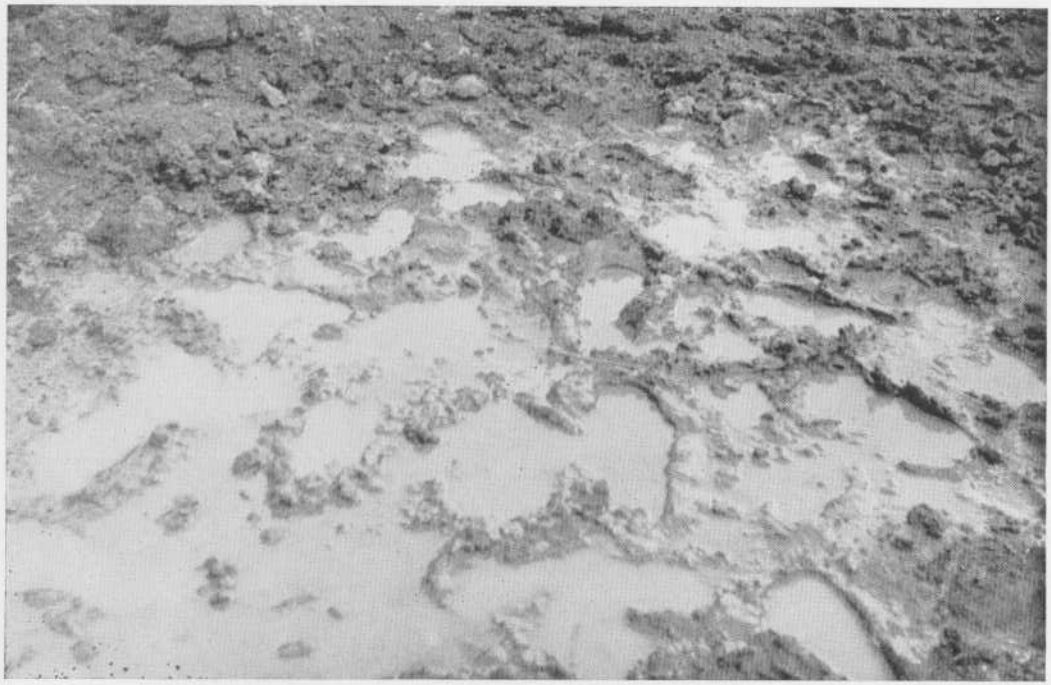
Before returning to the Australian arena, however, there are still some matters touching the military aspects of malaria in the East. In Colombo an A.I.F. hospital had been established as a halfway centre between the Middle East and Australia. Here also two returning brigades were stationed for a time. Malaria made up 14 per cent of the total admissions to the medical division of the hospital and local experience suggested that the strains of the *falciparum* parasite encountered there were more resistant to atebrin than to quinine. It was also claimed that quinine bihydrochloride instead of atebrin reduced the relapse rate greatly. It would seem likely that the question was one of absorption. The 2/2nd Australian Anti-Malarial Control Unit remained in Ceylon for a time, and did valuable work in an epidemic of malaria at Trincomalee, due to *A. culicifacies.*

MALARIA IN SOUTH-EAST ASIA

Meanwhile the 8th Division A.I.F. had been established in Malaya since early in 1941 and in February 1942 this force was involved in the bitter and tragic defence of the peninsula and Singapore. The experience of the 8th Division concerning malaria is of great value in retrospect. Unfortunately this experience, largely gained in captivity, could not be shared or applied in other fields of war, nor could the medical services do more than a limited amount to alleviate the invalidity or prevent the deaths that were inevitable in the conditions under which they worked. But it epitomises the military story of malaria under the shadow of defeat, though a constant medical rearguard action continued and undoubtedly saved the force from even greater losses. Although this part of the malaria story cannot be fitted into a chronological sequence with the accounts from the Pacific area, it is best told here so that it may show what malaria can do to a force striving with almost empty hands.

During the first phase of Malayan experience the incidence of malaria was low in the A.I.F. Control was good in the settled areas, and the influence of the Institute of Medical Research at Kuala Lumpur was most valuable. When jungle training began the incidence of malaria increased, particularly where troop movements were not correlated to anti-malarial measures. When the Australian troops took up battle stations, malaria became common. Then when the A.I.F. went into action at Gemas, the 2/4th Casualty Clearing Station, which treated large numbers of patients, found that medical casualties exceeded the surgical and most of them were due to malaria. The aftermath of this was seen in Changi after the capitulation when relapses of B.T. were frequent.

When the various working parties went out from Changi all of them had further experience of primary malarial infection. In the later phases of the war it was noticed when a hospital was set up at Thanbyuzayat at the northern end of the Burma-Thailand railway built by the prisoners of the Japanese, that new infections were moderate in number; but when in 1943 the line was pushed on through thick jungle country, the malaria



Human tracks making breeding grounds for mosquitoes.



Vehicle tracks making breeding grounds for mosquitoes.



(Australian War Memorial)

Malaria prevention—releasing Gambusia in stream in New Guinea.



(Australian War Memorial)

Malaria control—dusting with Paris green.

rate rose so high that whole units had practically all their men infected within a few weeks. Major W. E. Fisher found that when the different parties finally assembled in the terminal base at Nakom Paton, investigation in the large hospital there showed that 90 per cent of all the patients had had malaria. During their journeyings from one camp to another fresh infections were seen chiefly in the jungle camps, but in the base camps most of the attacks of malaria were recrudescent or relapsing.

It was evident that where conditions did not allow of any anti-malarial precautions infection rates were heavy. The accounts of medical officers unanimously show how futile all attempts were to employ protective measures. Night exposure was universal, most men did not return to their camps till after dark; in any case their quarters afforded no protection against mosquitoes. Even in the less uncomfortable base hospital camps where nets were available, these were often useless because mosquitoes had free access through the bamboo slats of the bed. In settled working camps medical officers were responsible for the malarial control of their camps, but mosquitoes usually entered freely from the neighbouring uncontrolled areas. Clothing, too, in the worst of the camps was almost non-existent. Drugs were always difficult to obtain and sometimes impossible. Quinine was usually supplied, but generally in inadequate amounts. The effect of this was twofold: clinical attacks were poorly controlled, or hardly at all, and treatment was perforce so inefficient that the camps were filled with men carrying parasites in their blood. Plasmoquine was virtually not obtainable after the fall of Singapore. A substitute was provided in small quantities on occasion by the Japanese, but it was toxic and unsatisfactory. The difference in areas where a reasonable supply of drugs was available was striking. Atebrin was sometimes supplied in small amounts and later was obtained through the American Red Cross.

In "F" Force and other forces in Thailand and Burma very heavy infection had been encountered on the road and practically the entire force was infected. Mosquito breeding was uncontrolled, chiefly of *Anophetes minimus* and *maculatus*; in other camps *A. barbirostris* and *phillipensis* were found. When enough supplies were obtained to treat clinical infections with adequate doses of quinine, beginning with 30 grains daily for 3 days, and of plasmoquine, the improvement in the chronic infections and in the longer spacing of relapses was apparent. Resistant infections were much benefited by the intravenous use of quinine. Cerebral malaria was not very common in the experience of most medical officers, but quinine given intravenously was found to be effective when available. Fisher thought that frequent small doses of quinine by mouth gave best results. The effect of inadequate treatment, which was more often seen, was depressing. Lieut-Colonel E. E. Dunlop in Tamarkan in 1943 was forced to use only 18 grains of quinine a day for 7 days, and 6 grains a day as a suppressive to the most severely ill. It is not surprising that blackwater fever occurred not infrequently. Major T. M. Pemberton, R.A.M.C., at Chungkai was even worse off, not being able to spare more than two or three days' treatment with quinine for each man. Relapses

were almost incessant in some of these enfeebled anaemic men, often occurring a few days after cessation of treatment. He graphically described "the large number of pallid, emaciated and tottery figures to be seen in the camps"—the toll of chronic malaria. Remonstrance with the Japanese here brought forth only 5 kilogrammes of quinine for a month's supply, which allowed each patient only 2 days on 15 grains a day. Pemberton justly pointed out that this was no more than a waste of quinine.

These multiplied experiences emphasised the importance of chemoprophylaxis. True, there was seldom enough quinine allowed for this purpose, and almost never enough atebrin, but in the instances where it could so be used the effect was most encouraging. There was evidence that atebrin was superior to quinine for this purpose. Fisher was so convinced of the value of suppression, largely through personal association with Field at Kuala Lumpur in 1941, that he strove to introduce it at Thanbyuzayat. The Japanese would allow only 3 grains a day of quinine for the purpose: this was futile and therefore not so employed. Later at Retpu the number of recrudescences was so large that the rules were disregarded and a daily dose of 6 grains was given. The result was almost to abolish active malaria in the hospital. At the base in Nakom Paton a fairly large scale experiment was carried out, after another convincing trial in a sectional group. Against considerable medical opposition in the area a suppressive dose of 6 grains a day was given to those who had completed treatment (seven days at 20 grains a day) for a third recent relapse. The number of relapses fell so sharply that in the group under this treatment which finally comprised 150 men, there resulted a saving of over 200 grains of quinine a day as compared with un untreated group. An experiment was also carried out on the effect on relapses of plasmoquine ordered early in 1945 at Nakom Paton by the Japanese. Analysis of the results showed little beneficial result in B.T. infections.

In this base area supplies sometimes ran out, and quinine was perforce reserved for the severest infections only. All care was taken to report mental clouding or the passage of darkened urine by patients. As a result of these precautions only three deaths occurred from cerebral malaria, and only one death out of the last seventeen cases of blackwater fever. Most of the attacks of blackwater fever began some days after the starting of treatment with quinine for a B.T. infection. Mixed infections with M.T. were of course common, and, as in all other fronts, it was found that the demonstration of only one type of parasite in the blood by no means precluded the possibility of a co-existing infection. Explosive onsets of blackwater fever were not common and anuria was rare. Haemoglobin figures below 40 per cent were also rare, and transfusions were usually withheld until haemoglobinuria had ceased. Several patients had more than one attack of blackwater fever.

One lesson which emerges from a study of the malarial experiences of the 8th Division is that thorough training of medical officers in all aspects of clinical and pathological diagnosis of malaria is essential. With regard to the latter an extraordinary amount of work was done in examining

slides, despite the scarcity of Giemsa, Romanowsky and Field's stains. Facilities for microscopic work were of course entirely lacking except in settled base areas. This made it all the more imperative to ensure that clinical diagnosis was of a high order. It is only to be expected that medical men whose previous clinical experience with malaria had been scanty or lacking should find difficulty, especially with M.T., the great deceiver. Men often arrived at a camp hospital with an indeterminate fever of some days' duration labelled "P.U.O.", but which was really malaria. Men might look reasonably well, but in a few hours might present the signs of serious illness, again due to malaria.

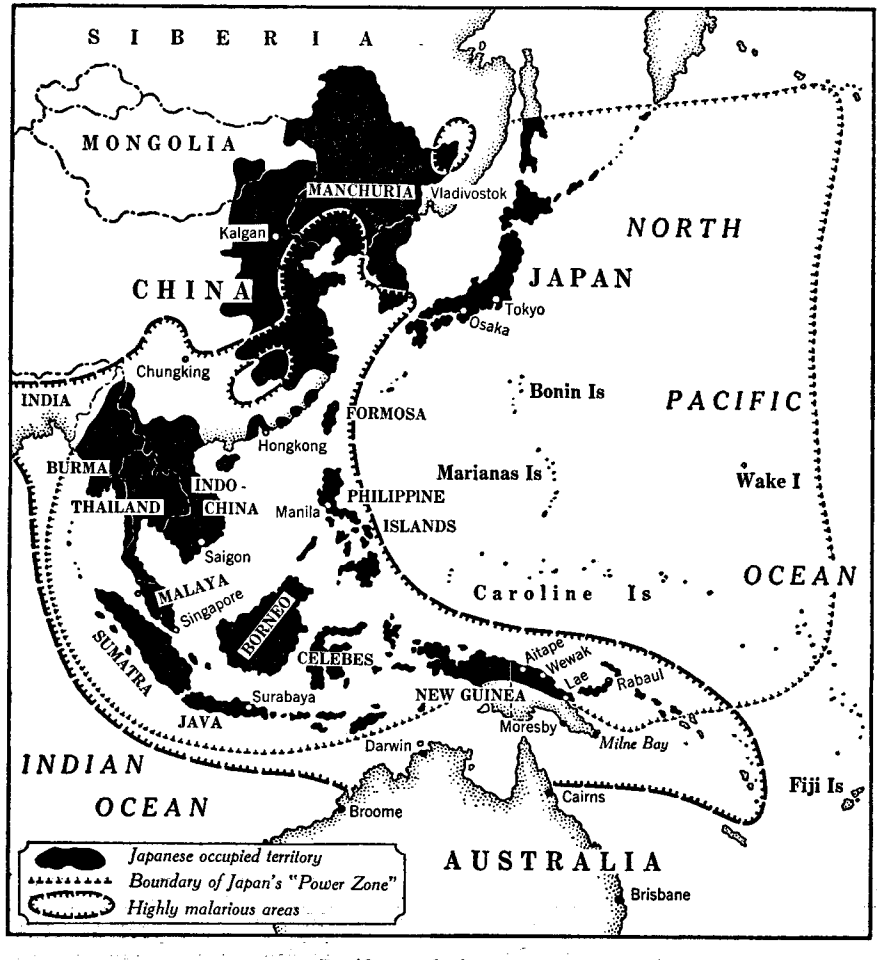
In the early days of training in Malaya prompt microscopic diagnosis was readily available, as in every well organised army, but the clinical picture seen in the jungle and in the working camps, where malaria was combined with all varieties of malnutrition and other tropical diseases was vastly different. The persistence of diagnostic ideas based upon descriptions of the so-called "classic" types of malaria has been referred to earlier. Under conditions prevailing in Burma and Thailand it is not surprising that difficulties in diagnosis arose. It was observed, for example, that in enfeebled men, suffering from malnutrition and other infections, response to treatment for malaria may not be as prompt as is usually taught and usually expected. Another lesson from Malaya was the need for further intensive education of all ranks in personal preventive measures. There is also a lesson for all communities in the disastrous effects and great danger of malaria when not under reasonable therapeutic control, and the futility of inadequate treatment. It is not surprising that malaria was an important cause of death among these men, weakened by disease and privation, but though the story is largely one of frustration, it shows that even with slender resources and devotion much may be done.

WAR IN THE PACIFIC AND THE THREAT OF MALARIA

When Japan entered the war in December 1941 and two divisions of the A.I.F. were recalled to Australia from the Middle East, events moved too swiftly for them to participate in the defence of the Netherlands East Indies, but an attempt was made to obtain a supply of quinine from Java, which produced 90 per cent of the world's supply. Urgent representations were made to the Australian Government setting forth a statement of the position by the Australian medical services with the object of obtaining an adequate supply while sea transport was still possible. Early in January 1942, 120 tons of quinine were paid for by the Australian Government but owing to probable fifth column activities none ever reached Australia, despite all endeavours of the advanced A.I.F. corps headquarters in Java.

While this was happening a grave warning of the danger of uncontrolled and untreated malaria was sounded in New Britain. The Japanese occupied Rabaul towards the end of January 1942 and part of the defending force, cut off and outnumbered, made their way back to New Guinea. Two hundred and fifty-two men of the 2/22nd Battalion escaped. Their medical

officer carried enough quinine for a month's treatment for the men, but after this was exhausted no less than 50 men died within the next five weeks. Almost all of the survivors were heavily infected with M.T. and B.T., and recovered only after many months' convalescence.



Pacific: malarious areas

This misfortune emphasised the importance of malaria to Australia. Before the war the civil health administrations of the Commonwealth and Queensland in particular were apprehensive of the dangers of malaria spreading on the mainland. Opportunity had been taken also for making surveys in New Guinea. Early in 1942 with a campaign impending in New Guinea and other islands to the north three problems relating to malaria faced Australia. These were: the prevention of malaria from spreading on the mainland; the control of malaria in New Guinea and other tropical islands; and the obtaining of malarial supplies from overseas.

THE MALARIAL RISK IN AUSTRALIA

Malaria was endemic in Cairns, and other low grade endemic foci were scattered through the north of the Australian continent. Below 20° south latitude the malarial risk was purely sporadic, but in North Queensland and the Northern Territory the epidemic risk was, and still is, considerable. In the past there had been epidemics, some of which were widespread and of considerable severity, a fact which their self-limited nature tended to obscure. In some of these the disease had been brought in, in others it originated in aborigines in whom there may be endemic foci and who are subject to the same periodic fluctuations of malaria as the other inhabitants. It was not likely that transmission would occur to any degree in the southern states, but north of 20° there was a real risk. Hence those concerned with preventive medicine clearly recognised the danger of introducing a concentrated military population into North Queensland or the Northern Territory where it could provide human material for an epidemic. All other factors were there; the climatic conditions, heavy rainfall in certain seasons of the year, the presence of both anopheline vectors and the parasite, whether intrinsic in origin, or as it might easily be with movement of men from endemic zones in the islands, extrinsic. The introduction of other vectors would also increase the risk.

In May 1942 a conference was held in Brisbane on mosquito-borne diseases. Here the Australian and Allied military representatives of preventive medical services and civil health authorities discussed the problems of dengue and malaria. It was agreed that further control measures were essential, and foundations were laid for future work. At this time a further effort was made to have entomologists attached to the army medical services. An appeal to the Acting Prime Minister through Professor Ashby, the Government's scientific adviser, was successful and four entomologists were appointed. Major I. M. Mackerras was appointed to take charge of entomological work at army headquarters, and later, with the rank of lieut-colonel became the Director of Entomological Services.

The Northern Territory was specially studied as a potentially dangerous area. Its history showed that malaria had smouldered there chiefly among the aborigines, with a few small epidemics of some severity that spread also to the white settlers. Between 25,000 to 30,000 troops were collected there early in 1942, and while they were not closely in contact with the usual inhabitants of the Territory, the aborigines supplied some labour on works like farms, and malaria among them was watched carefully, as the nomadic tribal remnants could spread the disease. The civilians in working camps made contacts with other groups of aborigines and in other ways were not easy to control from the point of view of public health. However, the chief danger of malaria lay in its introduction from outside Australia. Hundreds of refugees both from service and civilian sources had arrived in the Territory from Timor and other parts of the Netherlands East Indies; these were quarantined at Larrimah. The wisdom of this was shown by the occurrence of over fifty relapses of malaria, comprising many M.T. infections, in three months. An Independent Com-

pany and a R.A.A.F. squadron from Timor were found to be heavily infected. Americans from Timor were also believed to be infected. In addition certain A.I.F. units in the Northern Territory had served in Syria, and some of these produced a considerable number of B.T. relapses. The end of the wet season was expected to provide opportunity for more transmission by the anophelines of the Territory, which included a number of species. The most widespread was *annulipes,* which with *bancrofti* had been proved to be at least an experimental vector. *A. punctulatus moluccensis*[5] was also found and known to be a dangerous vector responsible for epidemics in Queensland and New Guinea.

The solution of this problem of the Northern Territory offered difficulties. It was certainly desirable to keep concentration of aborigines away from troops. The control of persons entering the country from overseas, by reason of the Japanese occupation, was not difficult—a matter of quarantine. Australian soldiers in the Territory who suffered from relapsing malaria were a menace; the only practical procedure here was to treat all relapses as they arose and to evacuate all men with proven infections south and not to allow them to return. The civil workers were also watched for evidence of fever, and similar measures taken. The destruction of larvae in so vast an area was not possible, but the neighbourhood of troop concentrations and air force establishments received special attention. These areas, at Darwin, Batchelor, Adelaide River, Katherine and Mataranka, were dealt with by malaria control units. Measures of personal protection and anti-malarial discipline in general were not easy to enforce in these widespread areas. Nets were barely sufficient, but their use was strongly advocated. The wearing of protective clothing was enforced as far as possible: some units, for instance, in the air force had none on issue. Repellent was scarce and its use half-hearted. All patients in hospital with active malaria were rigidly screened, and were evacuated south when their acute symptoms had abated. Further measures taken were to arrange for a conference between all Allied services involved so as to ensure uniform action, particularly with regard to the notification of all cases of malaria under two headings, those contracted outside Australia, and those contracted in Australia. Most important of all was to control the entry of possibly infected troops. Steps were taken to prevent troops leaving malarious areas from entering the Northern Territory, and, as just pointed out, to remove all infected persons from the Territory. This policy was strictly maintained: troops infected with malaria when coming out of New Guinea were taken direct to areas free of anophelines capable of acting as vectors.

The problem in Queensland was complicated by the need for terminals for movements of troops and supplies by land, sea and air. Townsville and Cairns, well equipped ports, were of obvious importance in this respect, but the malarial risk had to be considered. Cairns was within the

[5] There has been some confusion over the naming of the varieties of *Anopheles punctulatus.* The names *"moluccensis"* and *"typicus"* are used in this account as they were in general use by Australian medical officers and others. It is recognised, however, that the names *"farauti"* and *"punctulatus"* are accepted as correct.

malarial belt; Townsville was believed to lie within the belt also, but early surveys fortunately proved this not to be so. The epidemic hazards of Cairns and the other permanently endemic areas in the northern coastal districts emphasised the need for areas safe for troop concentration.

MALARIAL CONTROL IN CAIRNS

At the end of June 1942 a conference was held in Brisbane on the mosquito-borne diseases, at which Sir Raphael Cilento, Director-General of Health and Medical Services in Queensland, reported an extensive outbreak of malaria among civilians at Cairns. This outbreak had begun in March 1942; by the end of July some 500 cases were recorded, 50 of which were in service personnel, and the epidemic was increasing. Dr J. H. L. Cumpston, Commonwealth Director-General of Health, released Dr G. A. M. Heydon from the School of Public Health and Tropical Medicine in Sydney for a special investigation of the mosquito vector, which had never been accurately determined. Surveys of the area were also made by Colonels Fairley and Holmes, the Army Directors of Medicine and Hygiene. Major Mackerras and Captains A. R. Woodhill and F. H. S. Roberts were detailed for further entomological work in Cairns. The malaria in Cairns was benign tertian in type, as it had been in previous years, but it was thought possible that this extensive epidemic of 1942 was related to the influx of refugees from the north. The demonstration of sporozoites by dissection of the mosquitoes found in the field surveys proved that the vector at Cairns was *Anopheles punctulatus moluccensis,* identical with the vector in New Guinea. This discovery was of the first importance; it clarified questions of control and unified the vector problem so far as the Services were concerned. This mosquito did not favour the extensive swamps, such as those on the outskirts of parts of Cairns, but bred chiefly in other sunlit waters. Surveys showed that it did not extend south of Ingham. Other varieties of Anopheline, such as *amictus, annulipes* and *bancrofti,* were relatively scanty: they were potential vectors, but not responsible for this epidemic.

It was certain that a reservoir of gametocyte carriers existed in Cairns, since treatment of civilians usually consisted of the administration of quinine only, and was often incomplete and not medically controlled. Surveys of the population were carried out by the Queensland Health Department, and laboratory investigation was made available by the Commonwealth Health Services. All service patients in Cairns were now evacuated to Atherton, where, in a vector-free environment, full standard treatment was given. Attempts were also made to control civilian treatment, to some extent, by appeals for the abandonment of inefficient self-treatment, and by obtaining the cooperation of civilian practitioners to whom full laboratory service was available. A public meeting was addressed by the A.D.M.S. of the 5th Division stationed near Cairns, Colonel S. H. Lovell, and efforts were made by him and by Colonel Holmes, to disseminate knowledge among civilians. A house to house survey organised by Cilento, showed that of 3,000 persons a diagnosis of malaria had been

made in 6 per cent, though the actual figure was thought to be higher, about 7 per cent. Adequate supplies of quinine, atebrin and plasmoquine were made available at the Cairns District Hospital. In order to deal with the carriers of parasites a plan was devised for home treatment by drugs supplied through the army, which also provided help to carry out a campaign of adult mosquito destruction.

In June 1942 none of the Australian troops, except those who had had oversea experience, knew anything of malarial discipline. Protective clothing was not available in most units and was unpopular. Nets were obtained and were soon in use. The pamphlet "The Prevention of Malaria" was circulated among combatant officers and senior N.C.O.'s in the area and the subject publicised as much as possible. Fortunately the discovery of the vector saved much labour. The large swamps now did not require extensive spraying, though the actual breeding grounds needed close attention. These matters fell within the scope of army malarial control units, which carried the whole burden of the early control work at Cairns. Arrangements were made also to introduce *Gambusia* into the swamps in case *A. bancrofti,* which bred there, should be of importance.

The chief concern of the army medical services, of course, was not to deal with the civilian epidemic, but to control malaria in the Cairns area, as the possession of a malaria-free base in North Queensland was essential. This outbreak emphasised the suitability of the Atherton Tableland as a training area. With a bracing pleasant climate, well above sea level, well watered, offering forest and jungle country for training and yet convenient to the seaboard, it had many advantages. So much for the first Australian problem in malaria.

Meanwhile an occupation force had been in the Moresby area, and serious fighting was expected in New Guinea. It was essential not only to hold Port Moresby but to make it a safe malaria-free base. Medical surveys of Papua, the Mandated Territory of New Guinea, New Britain and other islands had been made before the war by members of the staff of the School of Public Health and Tropical Medicine.[6] These surveys had established that malaria was responsible for most of the morbidity and some of the mortality of the native population. Most of the infant mortality was due to malaria. Malignant malaria was the most common variety and benign tertian was also common: quartan, however, was rare. Blackwater fever was quite common and accounted for a number of deaths among whites. *A. punctulatus* and its sub species *typicus* and *moluccensis* were the most important vectors, and *A. bancrofti* was present too, especially in Dutch New Guinea, but it was a less efficient vector. Malaria was not found at an elevation of 3,000 feet or over, but since rapid transitions from mountains to coastal plains intensified the problems of prevention, there was no doubt about the formidable obstacle thus offered to military operations in these islands.

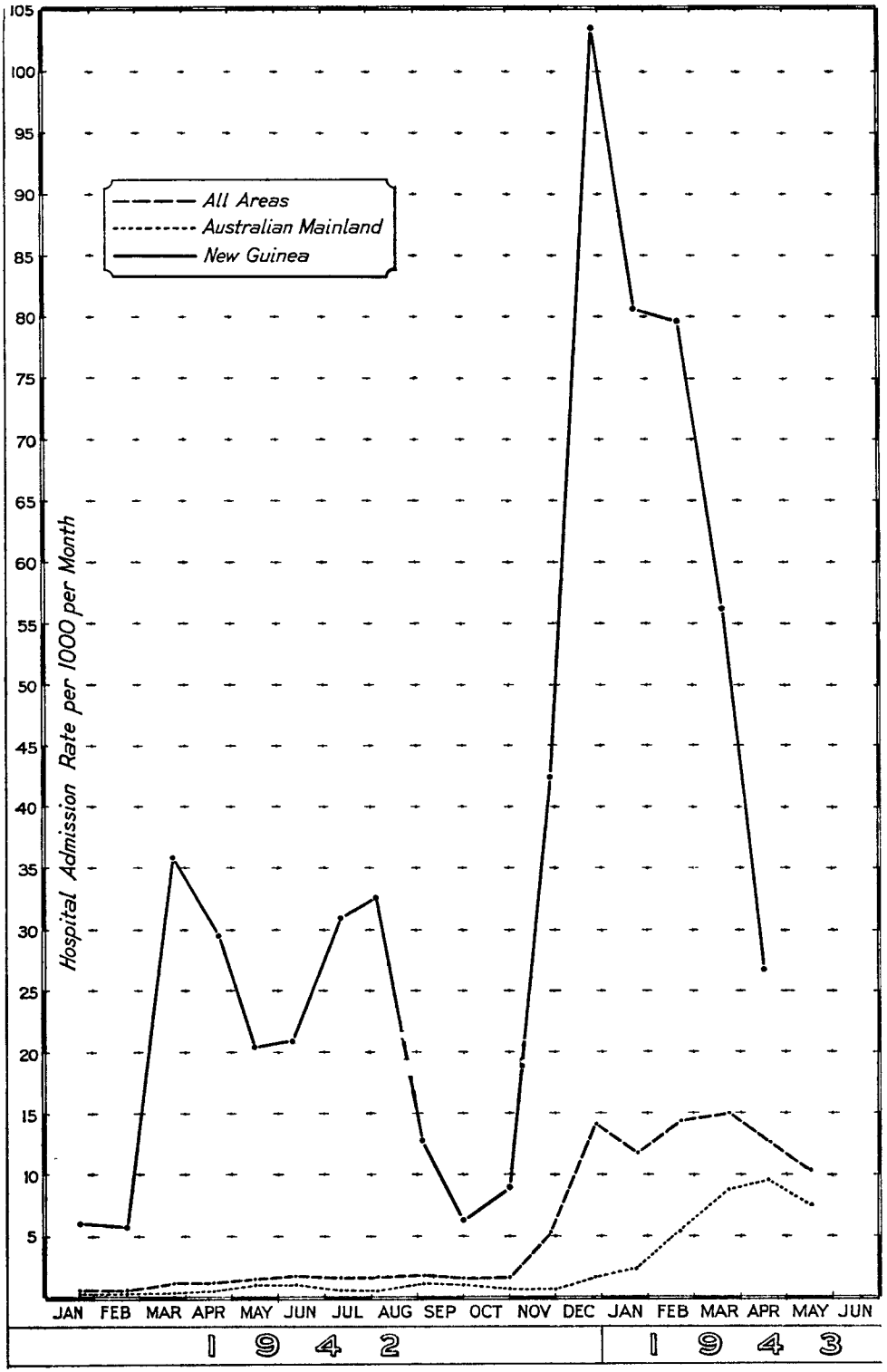
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6 This school was established by the Commonwealth Health Department, following up and extending the original establishment of the Tropical Diseases Institute at Townsville. The University of Sydney had accommodated the building in its grounds, and its head, Professor Harvey Sutton, was a member of the professorial staff.

MALARIA IN NEW GUINEA IN 1942

Fortunately the Moresby area differed climatically from the rest of New Guinea. While the whole of the territory of Papua was a very wet area, receiving rain from both the N.W. monsoon and the S.E. trades, Moresby only had 38 inches of rain a year, with a dry season from May to January, thereby resembling many parts of Northern Australia. In June 1942 Colonel Fairley, and Major Mackerras visited New Guinea. They found a high spleen rate in native children in widely separated areas on the south and north coasts, and confirmed that the areas likely to be occupied by troops were hyperendemic. What was much more disturbing was the high rate of infection among troops stationed in and near the Moresby area, which before the war had been well controlled and relatively safe. During the first six months of 1942, out of a force ranging up to 7,700 men and then beginning to increase rapidly, 1,184 patients suffering from clinical malaria had been admitted to hospital. As suppressive quinine was being taken throughout New Guinea Force the probable undisclosed infection rate would at least equal these figures. Surveys of combatant and field medical units supported this. On this basis the malarial casualties which might be expected in the fighting which was undoubtedly approaching were assessed at about 50 per cent. A garrison force had been in the area since 1940 and this had consistently suffered from malaria. The type of fever had been almost all benign tertian, but early in 1942 the greater dispersal of troops into less settled bush areas caused malignant tertian to appear. Up till recent times laboratory facilities were practically absent, and searching technical methods such as the use of thick films had not been used. Arrangements were then being made for the distribution of microscopes and stains to all medical units, including the convalescent depot, and more hospital accommodation was provided. Plasmoquine had been lacking for treatment, an omission which possibly had some bearing on the carrier rate disclosed on making a local survey of troops. No less than 25 per cent of men had gametocytes in their blood at the end of a course of treatment of quinine and atebrin.

The control of *A. punctulatus* in the Moresby area was a formidable task, though this would be lessened somewhat as the dry seasons progressed, and the river levels fell, thus limiting mosquito breeding in back waters and pools and seepages into swamps. This vector preferred clear sunlit water on the whole, but it would also breed in hoof and wheel marks and tins so freely provided by military communities. In the immediate vicinity of Moresby control offered less difficulty and much valuable work had already been done. If personal methods of protection could be enforced, conservation of quinine was thought possible by ceasing suppression during the dry months, since supplies were meagre. Bombing raids by the Japanese had scattered the natives, and thus eliminated the great part of the native reservoir of infection, but unfortunately there had grown up a military reservoir among the troops themselves. Strict control of natives entering the area was instituted by A.N.G.A.U. (Australian and New Guinea Administrative Unit) and their segregation from the troop



Hospital admissions for malaria, Australia and New Guinea, 1942-1943.

areas was arranged. Plasmoquine was supplied for completion of treatment, and healthy carriers of gametocytes could be dealt with either by "blanket treatment" after surveys or by suspending suppression and treating the resultant overt attacks.

The particular importance of dealing promptly with the malarial problem in Moresby lay first in the necessity for having a malaria-free base on the island, and secondly, in realising that it was a seasonal problem which would inevitably be more difficult in the wet season when breeding would get out of hand, and thirdly in instituting a strict anti-malarial discipline before the wet season arrived and before troop numbers rose, as they must, to a much higher figure. In Moresby, as in Queensland, protective clothing was not available to all troops, and those who possessed it often did not wear it; they often cut off the sleeves of shirts and went about at night in shorts.

The middle of 1942 disclosed a serious position with regard to malaria in the troops in the South-West Pacific Area. Troops who should have been seasoned experts in avoiding malaria, and who had the advantage of being for months in a relatively safe area were without full equipment, deficient in anti-malarial training, and therefore without an active conscience. Technical medical aids to the diagnosis of malaria and the limitation of its incidence were still not adequate in amount. Supplies of mosquito nets were inadequate unless cotton could be specially diverted for their manufacture, and drugs were very short. Quinine supplies were rapidly becoming exhausted, atebrin and plasmoquine were scarce, stocks were dwindling, and neither drug was made in Australia. However, the areas where troops were concentrated were coming under better control, and by the middle of August 1942 the measures laid down in General Routine Orders were being carried out. These included the taking of 5 grains of quinine in the relatively safe areas and 10 grains in those more heavily infected, the actual taking of the drug being supervised by a non-commissioned officer. This and dress regulations were enforced by disciplinary action against offenders. These orders were repeated and implemented by force headquarters in Moresby and Milne Bay. Nevertheless, the medical appreciation of the situation prophesied heavy casualties from malaria when action took place at Milne Bay and in the Buna area on the north coast.

ANTI-MALARIAL SUPPLIES

While these preparations were being made, the question of medical supplies was sufficiently urgent to demand special action. In spite of urgent representations very meagre quantities of anti-malarial supplies had been received from overseas. Quinine of course was very scarce, since the fall of Java to the Japanese had removed the chief source of world supply, and very little had been received in Australia from the stock in the United Kingdom. Firm orders had been placed with the U.S.A. for atebrin and plasmoquine on behalf of Australia, the first country to use lease-lend for this purpose, but only small amounts had been received after considerable delay. Bobbinet netting of the standard type was very scarce, owing to

the diversion of loom workers in Great Britain to munitions and other wartime work. Good netting could be made in Australia, but unfortunately early orders had not been placed in England for the correct type of cotton yarn. Many of the nets then in use were unsatisfactory; either they allowed the female anopheline to enter, or else they impeded air-flow. Substitutes for bobbinet mosquito netting obtained from overseas or made in Australia had so far not been satisfactory. Pyrethrum was very scarce. Most of it was now produced in Kenya, since the pre-war output of Japan and of the Dalmatian coast were no longer available. This Kenya crop had been bought privately from America, and only two-sevenths were allocated to Britain, Australia, India, Africa and the Colonies, the remainder being absorbed by America, mainly for horticultural and civilian use.

Accordingly, in September 1942, General Sir Thomas Blamey, the Australian Commander-in-Chief, acting on the advice of the D.G.M.S., Major-General S. R. Burston, sent a military medical mission to Washington and the United Kingdom. Colonel N. H. Fairley, Director of Medicine A.A.M.C., Dr Adrien Albert, a research chemist with special experience in the acridines, and in the synthesis of atebrin, were appointed. The objects of the mission were to represent the truly serious position, particularly with regard to malaria in the South-West Pacific, to try to obtain adequate supplies of quinine, atebrin, plasmoquine and pyrethrum, and an efficient type of netting. The discussions in Washington and later in London had important results. It was essential to convince authorities in Washington and London of the serious urgency of the problem of malaria facing the Allied forces in the Pacific zone. Data collected from recent observations and past surveys were epitomised in a memorandum drawn up by Lieut-Colonel E. Ford, A.A.M.C., and illustrated by maps showing the extent of hyperendemic areas in which malarial transmission went on all the year. This was welcomed by the Medical Intelligence Branch of the Surgeon-General's Office, and the D.M.S., U.S. Navy and was widely circulated. In London copies were also circulated among the medical authorities of the services, the Ministries concerned and the Medical Research Council.

The position about quinine was faced. Just before the Japanese occupation Java was producing 1,000 tons of quinine a year. The Australian Commission strongly advocated the adoption of a 5 to 1 ratio quinine to atebrin in the calculation of world requirements; this basis was accepted and the Allied requirements were reckoned to be 200 tons of atebrin a year. Even if Java were retaken supplies of quinine might not be available, and if trees were destroyed some seven years would elapse before production of cinchona bark would be satisfactory. It was evident that the reserve of quinine, about one year's supply, must be conserved. In U.S.A. and Australia steps had been taken to restrict the sale, wholesale or retail, of quinine to its use for malaria; in the United Kingdom it could be obtained only on medical prescription, but could be used for any purpose. Later strong representations were made in authoritative quarters in England, and similar restrictions were introduced there. This was an

important matter, because without concerted action in the control of anti-malarial drugs it would be more difficult to have the distribution of these administered from an allied pool, by an allied committee. Obviously such a method of control would be an invaluable weapon in the critical struggle against malaria.

The possibility of using totaquine from the bark of trees grown in New Guinea was also discussed. Difficulties had been experienced in the insolubility of quinine sulphate in tablets, but it was found that if the salt was first exsiccated, some starch incorporated in the tablet and over-compression avoided, the trouble would disappear. It was clear in every way, however, that the Allied malarial war would depend largely upon atebrin. Most of the production had to fall on American industry. Britain could make 50 tons annually, but difficulties in manpower shortage, dangers of air attack on factories, and the necessity for importing several intermediary substances limited output. It was agreed that Australia could not make atebrin without a severe tax on the chemical industry: to make each ton of atebrin in Australia it would be necessary to import about 20 tons of raw materials. Australia was, however, able to help in effecting improvements in the synthesis of atebrin. Dr Albert made available his own experience and that of members of the drugs sub-committee of the Association of Scientific Workers, a body which had been engaged *inter alia* for two years past in improving the published methods of synthesis. As an outcome of their endeavours a team of twelve chemists had worked on this problem in the Universities of Sydney, Melbourne and Adelaide. The results of these researches were freely made available to manufacturers both in the United States of America and England, with some improvements in details of this exceedingly complex synthesis. The tabletting of atebrin had given occasional trouble through undue variation in disintegration rates. The difficulty was to ensure rapid disintegration in water without undue friability of the tablet. One American firm had used a waxy coating, but by an improved method a single coating of shellac was used which was satisfactory. A compromise disintegration time of 13 minutes maximum was adopted by agreement. Examination by the Medical Research Council in Britain in 1942 showed that no difference in degree of purity of the drug could be detected in the German, American and British products.

Plasmoquine was made entirely by one firm in U.S.A., 1½ tons a year, while two firms in the U.K. produced together about a ton. The Allied requirements were considered to be 2¾ tons a year, which was the amount expected to be made in one year. One interesting point which emerged from the commission's inspection of plants in England was that there were instances of one firm finding technical difficulties with processes which were easily compassed by another. It was suggested that pooling of methods would produce much increased efficiency.

One of the objects of the Australian commission was to advocate the quinine-atebrin-plasmoquine treatment for malaria, and the substitution of atebrin for quinine in suppression. The U.S. Army and Navy adopted a standard treatment of malaria which was identical with that used and

found effective in the A.I.F. in the Middle East. At this time the question of toxicity of atebrin and plasmoquine caused some doubts and anxiety. Experiments on volunteers proved that there was no difference in the toxicity of atebrin from any source. It was interesting that American medical students taking 0.2 gramme of atebrin twice a week often complained of mild alimentary discomfort, whereas only 2 per cent of prisoners in Sing Sing showed symptoms. Australian experience had been that 0.1 gramme seldom caused symptoms. Though considerable experience had accumulated about atebrin, both as a therapeutic and a suppressive agent, it had never been given a mass trial on a very large scale. General agreement was reached that it was now the only choice as a suppressive, but in addition to its much exaggerated alimentary effects there were some questions yet unanswered. Like most dye derivatives, it had its peculiarities in the amount of drug fixed to various tissues. The difference in individual degrees of skin pigmentation showed this. But the effects of prolonged administration were not fully known: it was concentrated in the liver to a considerable extent, but the desirable and maximum suppressive dose had not been absolutely established. The usual suppressive dose was 0.4 gramme a week, though 0.6 gramme a week had been used also.

A little nervousness was felt in some quarters about the toxicity of plasmoquine, but Australian experience was that this was negligible provided that the dose of 0.01 gramme of the drug, reckoned as plasmoquine base, was not exceeded. Its gametocidal properties made it a most valuable drug in M.T., not only in reducing the number of carriers, but also in controlling relapses to some extent. Although a great amount of research was proceeding both in U.K. and U.S.A. in the quest for an even better anti-malarial drug, preferably a true causal prophylactic, no rival to atebrin was yet in sight. Indeed the loss of Java had given atebrin the pride of place that once belonged to quinine.

In Britain the pyrethrum position was discussed. Even though active research was proceeding on mosquito repellents, it seemed likely that insecticidal substances like pyrethrum would be necessary for sprays. Attempts were made to secure samples of the seed for local growing in Australia: some was then on its way, but this was of the medium grade, the highly toxic variety with high pyrethrin content not being available. Some 70 tons of the flowers were sent to Australia for processing. This relieved the position for a time, as stocks of flowers were practically exhausted, even though the use in Australia of pyrethrum in insect sprays had been restricted to the services. The total Australian annual requirements were put down at 200 tons, but doubt was felt whether this would be sufficient. Even at this period of the war a great part of the world's pyrethrum was still used for horticultural and domestic purposes. The commission considered that it would be better for the war effort if the Kenya supplies passed out of the hands of private buyers and if priorities for the use of pyrethrum were imposed so that considerations of war necessity and civilian health should have highest ranking. An improved method of spraying with pyrethrum solutions had recently been developed

in America by the U.S. Department of Agriculture and the U.S. Army in association with the Westinghouse Company. This was a "bomb" or dispenser which used compressed freon gas to distribute a fine spray under pressure. Production at that time was not fully under way, but it was evident that the freon bomb would be most valuable for killing insects in confined spaces like houses, trenches or aircraft.

Important information was also gained about insect repellents. Citronella was not proving very effective in the Australian Services, and its use was unpopular, partly owing to the greasy excipient. The Surgeon-General's Department in U.S.A. made available details concerning "Sta-way", "Indalone" and Ethyl-hexane diol, all synthetics of much greater potency. Sta-way, however, has been found to cause liver and kidney damage in animals, indalone stained clothing and was expensive; ethyl-hexane diol was effective for four hours, and could be applied as a cream, but it presented technical difficulties of manufacture in Australia where the resources of chemical industries were limited. On enquiry it was found by the commission that recent work on dimethyl phthalate showed that, although not so effective as ethyl-hexanediol, it proved very effective for both mosquitoes and mites ("chiggers"), as well as sandflies and fleas. The higher homologues of the ethyl and butyl series were not found to repel mosquitoes.

Dimethyl phthalate was introduced by the Standard Oil Company, who had patented it and issued a 25 per cent solution which had been found effective for some years in South America. Experiments showed that its toxicity was very low. This substance appeared to be the answer to Australia's needs, being twice as powerful as citronella, much easier to apply, and offering no difficulties in manufacture provided methanol could be obtained in quantity. Fairley and Albert aroused considerable surprise when they pointed out another virtue of this repellent which had been overlooked, its comparative cheapness.

The British view on repellents was that natural products should be favoured, so as to lessen the strain on their chemical industries. For Australia this attitude was not possible, as there was little chance of obtaining enough pyrethrum to use as a repellent as the British were doing. Accordingly a strong recommendation was made that dimethyl phthalate should be adopted as the standard repellent in Australia. British experts agreed to carry out further experiments on the toxicity of this ester. The importance of the South American work had attracted attention to it in Australia also at this time, and Captain Waterhouse had made some examination of dimethyl phthalate. R. N. McCulloch was thus able to start field work at an early date, and these independent studies were well advanced on Fairley's return. The first bulk supplies reached troops in New Guinea in March 1943.

The position about mosquito netting in U.S.A. and U.K. was not very encouraging owing to the scarcity of all cotton supplies. Looms were available in England, but not the necessary workers. A limited quantity only of the standard bobbinet netting could be obtained in America, and a

larger amount of a substitute netting of Nottingham or Lever's lace type. Unfortunately no army standard had been laid down either in Britain or U.S.A. for substitutes. There were many problems. Specifications were necessary to cover the size and shape of the aperture, anti-mildew processing, water-proofing, camouflage, shrinking and other details. Previous experience with substitute netting in the Pacific area had been unfavourable: nets sent to Australia both from India and U.S.A. had defective air flow, so that the troops would not use them. Further, their lack of camouflage made them impossible for use by forward troops, and they soon succumbed to mildew and rot in the tropics. The aperture of mesh was important. In substitute nets it was not octagonal, as in standard army bobbinet, but quadrilateral, and mosquitoes could wriggle through the longest diameter. A narrower aperture was necessary, and only "ungassed" yarn was to be used, in which the fine fibrils remained on the yarn and acted as a further impediment to the mosquito.

A difficulty arose over mildew-proofing for which there was no American Government standard, but, though production was held up for a time, it was agreed that the standard approved by the U.S. Quartermaster Corps would be adopted for all nets used in the South-West Pacific.

The discussion of these apparently small details had far-reaching effects for the Services of the Allied countries. Adequate supplies of netting were finally promised from America and England, and also of cotton yarn for manufacture in Australia. Difficulties were still being experienced in shipping priorities, through the complexities of lease-lend arrangements. These matters though not directly within the ambit of a scientific commission were of vital importance, as time was a crucial factor. In addition to the complicated procedure of procurement the International Supply Committee had recently introduced an additional check on the raw material exported, and this had caused further delays. The potential power of the War Department to repossess lease-lend material not shipped within 45 days was an additional source of anxiety. However, assurance was given by the British Ministry of Supply Mission in Washington that these difficulties were not formidable and could be overcome, and the closing months of 1942 gave promise of a much more satisfactory position with regard to anti-malarial supplies for the South-West Pacific zone. An appreciation of the serious position to be faced had undoubtedly been helped by the vigorous representations of this Australian commission.

Finally a most important matter was discussed and investigated. This was the problem of preventing the spread of malaria over Pacific areas hitherto free. The U.S. Navy had already had costly experience in the New Hebrides and heavy casualties from malaria were also being suffered in the Solomons. The danger of moving forces infected with malaria about the Pacific had been realised in U.S.A. A suggestion had been made to Field Marshal Sir John Dill of the British Joint Staff at Washington by Sir Philip Mitchell, Governor of Fiji, which was malaria-free, that malariologists should be appointed to various bases in the South-West Pacific. At conferences held in U.S.A. it was agreed that the problem was

that of the prevention of admission of anopheline vectors into this and other free areas. There had been a lack of coordination between some civil medical officers and some masters of American ships, and U.S. service officers, but recommendations were now drawn up to ensure the necessary action to prevent the spread of anophelines. On his way back to Australia Colonel Fairley stopped by arrangement at Fiji and found that energetic measures were being taken. In addition he suggested that any troops found to have malaria should be treated with plasmoquine, and that freon dispensers should be used in ships and aircraft, and that the services of an entomologist with experience in malaria be employed to advise concerning control measures near ports and airfields. These matters were duly reported to London and Washington.

MALARIA IN MILNE BAY

While these important steps were being taken overseas to secure and maintain anti-malarial supplies, stirring events were taking place in New Guinea. Two campaigns were proving how prophetic was the medical forecast of heavy malarial casualties in operations in hyperendemic areas. The first of these was at Milne Bay, the second included the terribly difficult action fought up and down the steep Owen Stanley Ranges and finally brought to a successful issue by forces converging on the north coast of the island at Buna and Gona.

Milne Bay is worth some detailed malariological study. The area is a roughly triangular one, occupied before the war by coconut and rubber plantations, bounded by hills and indented by the useful harbour of Milne Bay. It is virtually cut off from the rest of southern New Guinea to which access is gained only by sea and by air. Air communication is subject to weather delays and not without hazard. The terrain is flat and low; most of the area occupied by the Australians was only 25 to 100 feet above sea level. Jungle grew right up to the plantations, and many creeks fed the single river. The plantations were well drained before the war, there were sago swamps, neglected but originally harmless. Round the water front there was a good deal of malaria among natives; at Gili Gili, for example, the spleen rate was 90 per cent. It was in fact a hyperendemic area reasonably well controlled for white civilians. Both Australian and Japanese forces recognised the strategic value of its position at the south-eastern tip of the island. In July 1942 it was imperative that a force should defend it adequately against certain attack. Actually there was little time, and when the 11th Australian Division, as "Milne Force", occupied it, hurried preparations were made. Reinforcements arrived only in time for the action, and some field medical units had to settle in hastily selected areas. The wet season made the muddy area very difficult for vehicles on narrow and extemporised roads. Wheel tracks were everywhere, every one soon breeding mosquitoes. Slit trenches were also prolific breeding grounds for mosquitoes which attacked men seeking shelter during the frequent night air raids. Felled trees and palms blocked drains, so too did some of the roads and culverts hastily contrived by the engineers. *Anopheles*

punctulatus abounded, the *typicus* variety in small sunny waterholes, the *moluccensis* in the brackish water of the waterfront, among mangroves. Other anophelines were found such as *longirostris, subpictus* and *bancrofti,* but these were not of epidemic importance.

The first medical unit to arrive had some gear for malarial control work and early began the destruction of adults and larvae. One malaria control unit was in the area early, but its equipment was lost by the sinking of a ship. Up till September the Japanese had control of the sea by night.

The land action was only brief. Until 26th August when it began, the incidence of malaria was considerable but not crippling. The troops had had but negligible training in malarial discipline, but their newness at first saved them. Many of the reinforcements were in action within a period after landing not much greater than the incubation period of malaria. This was fortunate: it was after the successful conclusion of the brief sharp action that epidemic malaria attacked the force.

The malariologist's report on Milne Bay in July before hostilities had begun had stressed the need for at least twice the number of hospital beds usually provided in training areas in the north of Australia, for good laboratory facilities, reserve supplies of all kinds, an active malarial control unit, and provision of protection for troops. But at the end of August difficulties of transport and organisation still left the area with inadequate facilities. Brigadier W. W. S. Johnston, D.D.M.S. New Guinea Force, reported that the existing facilities of the whole New Guinea Force

"would not provide either for the best medical care of the troops or for the best means of maintaining the strength of the force, as bed space does not permit of retaining all cases on the island whose treatment can be carried out here."

This applied with special point to Milne Bay, where there was then no director of hygiene, thus adding to the burdens of the A.D.M.S., Colonel Maitland, who was severely handicapped without sufficient materials or labour. It was eight weeks after the loss of the malarial stores mentioned above before replacements arrived. This was due to lack of power to enforce priority of transport for such supplies; goods were later found to be lying in sheds at Townsville still waiting to be moved.

The R.A.A.F. in Milne Bay laboured under similar difficulties on a smaller scale. The secrecy of the original move of fighter squadrons to Milne Bay had been so closely preserved that adequate medical preventive arrangements could not be made. The Director of Hygiene and Tropical Medicine for the R.A.A.F., Group Captain Baldwin, was thus severely hampered, and anti-malarial discipline in the Milne Bay area was as unsatisfactory as in the army. The squadrons had only shorts and short-sleeved shirts, and the taking of suppressive quinine was not strictly supervised. Mosquito nets were issued but were quite unsuitable. In September it was necessary to rest these pilots, not only on account of their strenuous service against the enemy, but in part because of malaria.

It was not long before a dangerous reservoir of gametocytes was built up in the blood of the troops themselves. A little later a series of even apparently healthy soldiers was found to have as high a gametocyte rate

as 20 per cent. Concentrations of natives also increased the risk: in one area natives in camps within 500 yards of military areas were found to have high parasite rates, but after the administration of 0.02 gramme of plasmoquine for 3 days by an American unit, the local malaria rate was reduced. Even in medical units the medical officers and orderlies themselves increased the pool of available parasites. Where patients were accommodated on narrow stretchers they were frequently bitten through the nets, which touched them on either side if they moved.

After the occupation of Milne Bay the malarial incidence rose rapidly. Whereas in September when active operations concluded the rate was fairly steady at 33 per 1,000 per week, that is 1,716 per 1,000 per year, by December a sharp epidemic wave had begun which was responsible for 3,000 cases of malaria during the month. In September a bed allowance of some 7.5 per cent had seemed sufficient for the force, though medical authorities had all along advised a 10 per cent provision for areas with high sick rates. Now the rate for malaria alone was 82 per 1,000 per week, or 4,264 per 1,000 per year. During the week ending 25th December 1942, 1,083 men were admitted to hospital out of a strength of some 12,000. As Lieut-Colonel Ford[7] said with reference to epidemic malaria, an outbreak may be likened to a camp fire, but an epidemic to a bush fire. Medical units were overcrowded, many men were being inadequately treated in their lines, and others attempted covertly to treat themselves. Medical officers and others kept on their feet by taking increased suppressive doses of quinine. Had this alarming increase in rate continued, bounding upwards in geometrical progression as the parasite reservoir grew, the whole force would have been lost in less than two months. Evacuations of patients with malaria to the mainland were being made with a lamentable effect on morale. The only brightness on the horizon was the timely defeat of the Japanese invading force. Determined efforts by the medical service to obtain necessary supplies and native labour, and to tighten up loose malarial discipline produced only a weak response. An appeal was therefore made to General Blamey and, through the D.D.M.S., Brigadier Johnston, Lieut-Colonel Ford obtained an interview early in December with the Commander-in-Chief. He stressed the necessity for regarding the recent campaign areas as training grounds in malaria for subsequent operations. He pointed out the lack of consciousness of the destroying force in malaria among all Allied troops in New Guinea. Malarial discipline should be an integral part of unit discipline; "no officer is fit to command even the smallest body of men in a hyperendemic malarial area who does not have constantly with him the awareness of his responsibility". Personal protection must be enforced and breaches of discipline visited by punishment; the unfailing supply of all anti-malarial material, particularly suppressive quinine or atebrin was essential. Such responsibilities were incumbent on all troops right back to

[7] Lt.-Col. Ford officially was appointed Assistant Director of Pathology to New Guinea Force but unofficially was its malariologist. At that time the medical services had not been able to secure the appointment of malariologists, hence this device without which the effects of malaria on the force would have been even more serious.

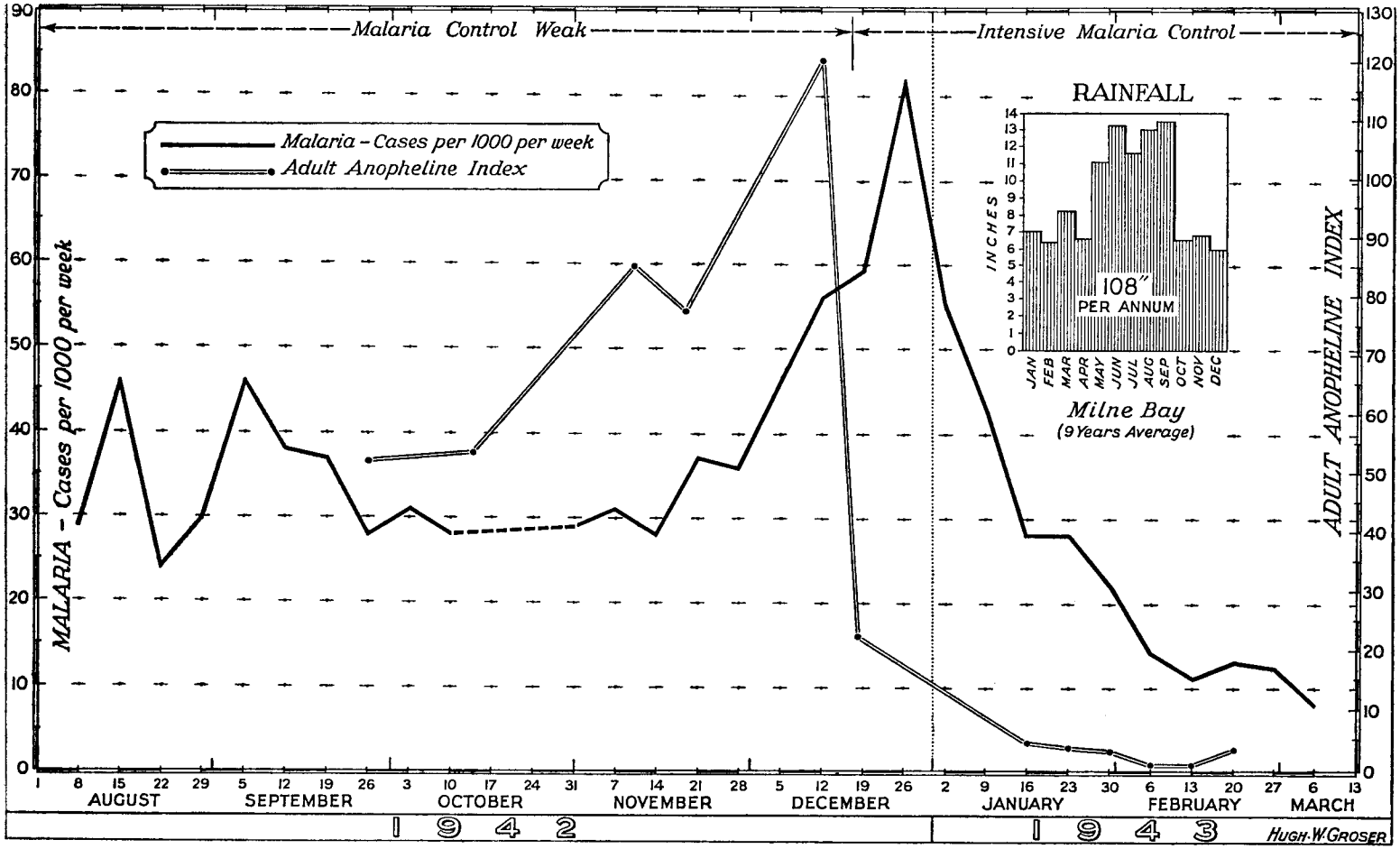
training areas. Ford pointed out that medical units in Milne Bay had been evacuating 300 men a week for weeks past, and 800 then awaited evacuation: about 5,000 men had been treated for malaria out of 16,000 in Milne Bay, and it was probable that practically the whole force was carrying infections temporarily held in check by suppressive drugs.

A request for higher priorities for all malarial work, particularly increased equipment and stores for malaria control, and for additional labour, amounting to 1,000 men, met with immediate response from General Blamey. By the middle of December intensive anti-malarial work began, 500 native labourers were made available at once, discipline was tightened and the wearing of protective clothing was compulsory under penalty. At the same time another malarial control unit arrived and delayed stores came to hand. A month later the 11th Division was replaced by the 5th, but even before this a dramatic fall in the anopheline index of the area began, and after the typical appropriate lag period, representing the incubation period of the infection, case incidence also fell sharply. There could be no doubt that the reduction in the malaria rate was due to reduction in infection by the mosquito. Three other important factors should be mentioned. The first was an order that no man would be evacuated from the area for malarial infection except for serious medical reasons; the second the segregation of native labourers and the third the resumption of plasmoquine in treatment. Some heavily infected units were also treated with plasmoquine in order to reduce the gametocyte reservoir. Mechanical methods of control such as engineering works, oiling, use of paris green and spraying were continued with vigour. The decrease in the infection rate continued when the 5th Division occupied the area. These men were already initiated into malaria control, having been in the Cairns area, and the incidence of malaria fell from 30 per week to about 10 a week within a month and diminished further.

In February 1943 many fresh R.A.A.F. units were moved into the Milne Bay area and concentrated efforts were made to institute malaria control. A mobile anti-malaria squad, with the help of allotted natives, joined in the preventive campaign. Unfortunately protective clothing was still inadequate in supply, but the figures of the R.A.A.F. for malaria soon began to show the same encouraging fall as in the army, and later in the year their rate fell to about 1 per 1,000 per week.

The malarial story of Milne Bay is one of a virtually closed community. The force, like some others in history, luckily fought an action while the malarial enemy was gathering strength; it was nearly extinguished by infection, but showed how remarkable a rehabilitation may occur once facilities are available and strong measures taken. It is fair to say that had not the medical services continued their undaunted struggles for control even when things were at the worst, so rapid a result could not have been attained later.

A month after the beginning of intensive malaria control in Milne Bay atebrin was adopted as the suppressive drug for the Australian armed forces, but the change was not fully implemented for a time. This aroused



Milne Bay: malaria in 1942-1943.

at first some of the doubts previously mentioned about the potential toxic effects of atebrin. Among aircrews in the air force, particularly pilots, there were at first serious questionings. An idea had gained a certain degree of credence that atebrin "lowered the ceiling" in high flying, owing to some interference with cell metabolism. Some pilots were averse to being bereft of their accustomed quinine. The experience of the U.S. Air Force indicated that there were no special drawbacks to atebrin. After some delays this reluctance was overcome and eventually atebrin was used by all services. The bogey of toxicity of plasmoquine was not so easy to lay. It was well known that the therapeutic dose is close to the toxic dose, that some people are sensitive to it, and that substitution in error of tablets containing 0.02 gramme plasmoquine base for the usual 0.01 gramme would cause abdominal discomfort and cyanosis due to the breakdown of haemoglobin. Such mistakes were due to the differences in strength of different preparations, poor packaging without clear description of the contents in large type, and lack of understanding of the actual potency of the different combinations of the base. The question was particularly important in Milne Bay for there, with malaria in the zenith and antimalarial morale at the nadir, plasmoquine so fell into disrepute that it was virtually abandoned when it would have been valuable in diminishing the gametocyte pool rapidly being built up in the force.

In order to cope with this situation a short treatment was introduced as a temporary measure. This was 5 days of quinine 30 grains a day, followed by 5 days of quinine 15 grains and plasmoquine 0.03 gramme a day. Atebrin was added to the course after the initial quinine as in the standard course if the medical officer considered it advisable. It was hoped that this would control attacks, maintain a presumed premunity and kill the gametocytes. Most of the gametocytes seen in films were crescents, for malignant tertian was the predominant type then in Milne Bay, comprising 90 per cent of the infections. The rest were benign tertian with an occasional quartan. Quartan malaria had a high incidence in native children but, as expected, was not often seen in soldiers, as *Plasmodium malariae* does not appear to be a ready or quick infecting type. This question of controlling the gametocytes after suppression of the primary fever was regarded as important in the Australian forces and will be referred to again presently.

It may be pointed out here that it is hard to present convincing statistical evidence involving calculation of gametocyte rates because of the laborious technique necessary in order to obtain accurate figures. If the standard of 8 to 10 gametocytes to 1 cubic millimetre of blood as the minimum infecting dose is accepted, one half or preferably one cubic millimetre of blood must be examined completely by thick films. This labour can only be appreciated by attempting it. Using this method, Mackerras found the following figures in an illustrative series.

	Number examined	Spleen rate	Parasite rate	Gametocyte rate
Native children . .	30	93%	70%	33%
Working natives . .	265	70%	15%	3%
Patients at end of quinine-plasmoquine course .	150	0	4%	4%
A.A.M.C. personnel (working) . . .	109	5%	6%	0
Infantry personnel (working) . . .	47	6%	25%	21%

The 47 infantrymen surveyed had not taken plasmoquine during previous attacks of malaria, owing to a prejudice against this drug which began in American units in Milne Bay and spread over most of the units in the area. Atebrin suppression had begun some weeks previously. The 109 A.A.M.C. men owed their freedom from gametocytes to their superior suppression.

Before leaving Milne Bay we should understand clearly the difference made by adequate control. Improved conditions were not only gained but maintained. The malarial rate fell to figures below 5 per 1,000 per week, there was no strain on medical units or on evacuation of the sick, unit discipline in the Australian forces was excellent, permanent road and drainage works made great improvements, such as the abolition of swamps, and making work in the jetty area safe and possible. Even with the improved conditions in the early months of 1943 malaria in Milne Bay caused 8,099 casualties in the period from October 23rd 1942 to April 24th 1943.

THE KOKODA-WAU-BUNA CAMPAIGN

Now we must turn to Central Papua. The arduous struggle on the Owen Stanley Ranges which ended in the repulse of the Japanese to the coast had not produced much malaria, for there was little transmission at the higher altitudes. But when Australian and American troops undertook the encirclement of the Japanese in the area including Sanananda, Buna and Gona three months of persistent fighting took place in swampy coastal country where malaria was hyperendemic. Once again the same cycle was seen; increase of breeding areas, increase of mosquitoes, rising infection rates, the creation of a reservoir of parasites in the blood of the troops, and finally an epidemic. Unlike the forces in Milne Bay these troops did not enter that ordeal after brief periods of establishment and action. They were already tired and undernourished, and were poorly equipped to protect themselves against infection. Suppression had been discontinued on the ranges, where mosquito transmission was unlikely, in order to conserve stores in that difficult country in which native carriers and air dropping were the only possible methods of maintaining supplies. Drugs, repellent cream and nets had not reached Kokoda, where there was a practicable airfield, before the action on the plains began. Even quinine did not arrive there for nearly a month.

Troops were also engaged in the operations on Wau and Bulolo, converging on the coast. The malarial danger in the high Wau area itself was slight, but lay in the precipitation of men from a safe area to the highly malarious areas in the Markham Valley with insufficient protection. Without great care the heavy epidemic of Buna and Sanananda might have been repeated. In this latter area between Kokoda and the coast the true incidence of malaria can only be guessed. Under existing conditions it was difficult to avoid infection. It was reported that at Soputa 90 per cent of the troops in the area were infected in a month. The declared overall rate for operational troops in the Buna and Wau actions was 22.5 per 1,000 per week, rising to a peak at the end of January 1943 when the rate was 48 per 1,000 per week, or 2,496 per 1,000 per year. Taking the same six months' period as for Milne Bay, 23rd October 1942 to 24th April 1943, the number of patients admitted with malaria to medical units was 11,638; this brings the total of cases of malaria reported in New Guinea for this period to 20,272. The total casualties for this period due to tropical diseases was 29,101 whereas battle casualties were 6,154, a ratio of 4.7 to 1.

Fairley has pointed out that the consolidated figures, even allowing for admitted understatement, give no idea of the impact of malaria on the forces. Many men admitted to hospital were suffering from hyper-infection, and severe M.T. infections were common. Blackwater fever was occasionally seen, and by no means always in men who had been for sometime, that is, a number of months, in the country. Thousands of men were treated in their lines or treated themselves.

Some idea of the widespread degree of infection may be gained from the results of surveys made on men after their return from the area. The 18th Australian Brigade was in action some 5 weeks in the Buna-Sanananda area and left there for a base area a few weeks later. Examination then showed that 7.3 per cent of the men who had had an attack of malaria still had parasites in the blood, while 26 per cent of those who had not had an attack also carried parasites. Some of these men had been in Milne Bay previously, but in proof that Buna was an equally dangerous area, similar surveys of men who had been only in Buna showed corresponding figures of 4.9 per cent and 29 per cent. Surveys were made later of men who had been in the sharp fighting of the Wau campaign in highly malarious areas. Less detailed examination was possible, but the frequency with which enlargement of the spleen was found in men who had no clinical history of malaria showed that a high relapse rate might be expected. In this series some interesting figures were obtained concerning the average time between the initial attack and the first and later relapses; these periods were 8.5 weeks, 8 weeks and 10 weeks.

Early in 1943 the divisions concerned in the actions at Milne Bay and Buna-Gona-Sanananda were withdrawn to Australia to rehabilitate and train in the more salubrious environment of the Atherton Tableland in North Queensland. There it was soon evident that practically the whole force had malaria, as most of the men had relapses of benign tertian fever.

It was apparent too that there was a sharp difference between these relapses and those seen after the Syrian campaign. Relapses now appeared earlier, and it was observed that the types of infection encountered in New Guinea were more severe and difficult to control.

We may anticipate here the happenings when the troops of the II Australian Corps were withdrawn to the mainland and they were allowed to proceed on home leave. It was inevitable that many would suffer from relapses of B.T. while in the southern States, as it was certain that suppressives would not be regularly taken during that period, although the taking of 0.1 gramme of atebrin thrice weekly was an order. Soldiers were instructed to report for advice to military hospitals or public hospitals or to the nearest area medical officers. Large numbers were admitted for malaria to military hospitals throughout Australia. Most of the "originals" who had been five months in New Guinea and had been in the Buna-Gona area were already infected, and after their return to their units presented the problem of latent malaria. Medical authorities thought that none of the original brigades would be fit for hard operational training for three months. Many of the men looked pale and tired. Anaemia was not uncommon, particularly in those who had a palpable spleen. Investigation in hospitals showed that eosinophilia was not infrequent and, as expected, this was found to be due to hookworm. Study of a considerable series showed that a recession of the eosinophilia was sometimes due to the occurrence of malarial relapses. The hookworm infestation was not severe, and it was not expected to be a serious factor in debilitating the men.

After several months relapses became less frequent and the condition of the men was obviously much improved. Malignant malaria was not common among these men. In one hospital in Queensland the first 1,000 cases of relapsing malaria produced 38 of malignant tertian, but in the second 1,000 there were only 3. Unfortunately, despite all warnings, a few deaths occurred among men who did not report when they fell ill. Others were seriously ill on admission to hospital but recovered rapidly. In a few instances too, rupture of the spleen occurred. But the problem was almost entirely one of relapsing tertian fever. In order to detect latent malaria suppressive drugs were suspended for a week and blood films were then examined. If parasites were found quinine and atebrin were given in a hospital, and the plasmoquine part of the course continued in a convalescent depot.

As the men became more physically fit for rigorous training there were several important problems to solve. The question of more intensive antimalarial training was, or should be, only one of organisation. But more serious immediate matters were involved when malarially infected troops were trained in the Queensland coastal areas. It was necessary to survey the most appropriate areas for bivouacs from the malarial point of view, for night exercises carried some risk of dissemination of malaria. Instructions were given that troops in moving to a bivouac area would proceed direct and not to be staged elsewhere in an area of potential risk. The men

were issued with mosquito nets before moving and took suppressive atebrin for a week beforehand.

At this time difficulties were occasionally experienced in various parts of the mainland and New Guinea in establishing prompt and complete control over the primary fever. Fever would recur even during a course of treatment, and parasites were sometimes then found in the blood. In some later series carefully observed, as in Nadzab, no parasites could be found in the blood even after prolonged search. In some instances it seemed likely that there was another cause for the fever, such as dengue fever, but in places like the southern States of Australia there was no dengue present. Where relapses occurred during or soon after completion of a course a variant of treatment was adopted. Intravenous quinine 10 grains on the first two days of the course, as well as 20 grains by mouth, 30 grains on the third day, 9 tablets of atebrin the fourth day, 6 tablets the fifth day, and then 3 tablets for three successive days. The most obvious explanation of these recurrences was that drugs were either not taken or not absorbed. There seems little doubt in carefully supervised series that the trouble was sometimes one of absorption. The question will be discussed later.

ANTI-MALARIAL DEVELOPMENTS IN 1943

By March 1943 it was necessary to review the whole malarial position. Some brief account of the measures taken is necessary, for it is really germane to the clinical study of the disease for whose understanding, treatment and prevention a penetrating knowledge of all the factors is essential.

One step had already been taken that was obvious and inevitable, but was even more important than was realised at the time, the adoption of atebrin as a suppressive drug. The dosage recommended was 0.1 gramme daily for six days a week in hyperendemic areas and 0.1 gramme daily for four days a week (or 0.2 gramme twice weekly) in areas where malaria was endemic, but not defined as hyperendemic by the D.G.M.S. or his senior representative in an area. The original suppressive dosages of atebrin were largely based on experiments carried out on semi-immunes in Malaya, thus accounting for their inadequacy to give full protection to fully susceptible whites under service conditions. The same fallacy had been observed in relation to quinine in the Balkans during the 1914-1918 war. The hesitation at first felt at abandoning quinine was reflected in one of the earlier orders which recommended a compromise in hyperendemic areas, in which the total weekly suppressive dosage was 30 grains of quinine and 0.2 gramme atebrin weekly. Hyperendemic or highly malarious areas were defined as those in which the splenic index was over 20 per cent or in which malaria assumed serious proportions in unseasoned troops.

In February 1943 the "New Guinea Allied Conference on Tropical Diseases and Hygiene" was formed under the aegis of New Guinea Force. This body was concerned with the educational aspect of preventive medicine. The subjects covered at its meetings ranged from purely scientific and technical reports to methods of propaganda to troops. Many of the contributions were of a high order and from its discussions flowed an

energising influence. Though the Allied Conference had no direct power of executive action its influence was well diffused. Methods of propaganda were particularly discussed at the earlier meetings, such as leaflets dropped from the air, posters and instructional films. Material was supplied for *Guinea Gold* and *Salt,* service magazines circulated among the troops. This was specially important, as articles had been published by well known writers, whose previous civilian experience was often not relevant and whose views were sometimes positively likely to do harm. Again and again it was found how far from military reality were the tenets of the pre-war civilian in the tropics. It was also pointed out later to New Guinea Force headquarters that a pamphlet "The Native Carrier" from the Allied Geographical Section advised seeking shelter in friendly villages, a course definitely not favoured by malariologists. Another pamphlet "Getting about in New Guinea" was found to contain dangerous advice about drinking water, and harmful information about malaria which contravened official instructions.

In March 1943 General Burston, on the advice of Colonel Fairley, made representations concerning the forming of a combined advisory body on tropical disease. Discussions took place between the American and Australian Medical Headquarters, and these resulted in the setting up of a body of experts who were to act in an advisory capacity to the Supreme Commander in the South-West Pacific Area, General MacArthur. This "Combined Advisory Committee on Tropical Medicine, Hygiene and Sanitation" comprised representatives of all medical services of both Allies, with Colonel Fairley as chairman and Colonel Holmes as chief executive officer. This committee, collecting information from many sources, had far reaching influence, and many important directives were made by General MacArthur on its advice.

During March another Australian mission was sent to U.S.A. and U.K. to coordinate the supply of medical requirements to Australia and the combat zones in which its forces were operating. This was done at the instance of the Medical Equipment Control Committee, a body that was fulfilling the important function of controlling supply and distribution of all medical material in Australia. Mr B. Egan, its representative on behalf of the Division of Import Procurement, and Colonel C. W. Ross, carried out this mission. As a result of the contacts made by this mission and by Lieut-Colonel J. A. Doull of the United States Army Medical Corps who visited Australia to investigate the control of supplies under "lend-lease", an improved flow of material soon was obtained, chiefly at first from U.S.A. for lend-lease and later by export from U.K. There was reason to hope that by the end of 1943 no lack of material would hamper the increased efforts made not only against the Japanese but also against tropical disease, in particular malaria.

Meanwhile additional medical units had been brought into New Guinea, preventive work was pushed on in the field and efforts were made to arouse the consciousness of the forces in the island to their personal responsibilities. The newly formed advisory committee as one of its first

acts placed before General MacArthur the lessons learnt to date in tropical warfare, particularly the dangers of beginning actions before anti-malarial supplies were available, and before anti-mosquito measures were established. The committee made recommendations as to the anti-malarial measures necessary for operational forces in highly malarious areas. These covered (1) training and instruction of troops in personal protection (clothing, nets, and repellents), suppressive use of atebrin and methods of destroying mosquitoes; (2) malaria control organisation within military units, including a recognition of the responsibility of commanders thereto; (3) issue of necessary personal supplies to soldiers before embarkation; (4) measures to be taken in connection with movement of troops to malarious localities, including the use of malariologists attached to such forces and the issue of necessary unit supplies; (5) discipline; and (6) priority of malarial supplies. The routine use of dimethyl phthalate as a repellent was advised through the whole South-West Pacific Area. Production was then proceeding in Australia with priority over munitions, and was expected shortly to supply the needs of the Australian Army and Air Force.

It might perhaps be thought that experiences in New Guinea to date would of their own relevance and force ensure that a striking reduction of malarial casualties would be effected in the next campaign. But human beings are not built like that, and in the early months of 1943 even officers of field rank could sometimes be seen in the Moresby area breaking the strict rules about clothing. Difficulties were still occurring with clothing in other ways. Men of the R.A.A.F. and R.A.N. were still arriving in malarious areas wearing shorts; the mobility of units of the air force created a particular problem, and some time elapsed before this service was equipped with protective clothing. Even under static conditions only strict supervision could ensure that suppressive drugs were taken or nets used. Engineering works still provided many breeding places for mosquitoes, many of which though avoidable were unheeded by the perpetrators. If there were those who were still careless of counsel there were also those who wished to follow their own notions. Striking at the appropriate time General Burston issued a new Technical Instruction No. 59, which consolidated and replaced all previous instructions. This was drawn up by Colonel Fairley and unified methods in all areas.

THE HANDLING OF MALARIA IN AUSTRALIA

The scene now shifts to the mainland of Australia, where the return of thousands of soldiers suffering occasional relapses of malaria aroused great public interest. This interest invaded the political spheres as was natural, and Sir Earle Page (himself a doctor) who had voiced some criticisms of the medical aspects of the campaigns, was asked by the Prime Minister, Mr John Curtin, to investigate and report. As a result of this investigation, for which full facilities were given Sir Earle Page in all areas, a complete report was presented covering the question of possible spread of infection in Australia, measures to prevent malarial infection, treatment of the

disease, including methods and places where it is best carried out, strategical considerations of malaria and army dietary in relation to health. The report emphasised the necessity for taking measures to control malaria in Australia, and with this end in view to treat malaria in the army in New Guinea and Queensland for preference, and not in potentially malarious areas. Priority for malarial supplies was advised and recommendations were made for improvement of army diet. This report amply vindicated the policy adopted for prevention and control of malaria by the Australian Army Medical Services, whose leaders welcomed the support thus given to their advice. Some important matters were also discussed with reference to the strategic aspects of malaria, such as the importance of malaria-free bases, the disposition of forces with relation to malaria, and the importance of keeping Northern Australia free from malaria. In this report the exploitation of night bombing to inflict malarial casualties on the enemy was mentioned. Such strategy may well come into the scope of military planners, but is quite foreign to the aims and practice of a medical service while it claims the protection of the Geneva and related conventions for the sick and for its own personnel. It seems strange that the Government should ask for the inclusion of strategic considerations in a report on medical matters.

The problem of preventing malaria from gaining a foothold on the Australian continent has already been discussed. It is now interesting to see how it was affected by the return of two malarialised divisions to North Queensland. More than ever was it necessary to ensure that no troops affected with malaria arriving at the mainland from an endemic area would be sent to a potentially malarious area in Australia. This policy was laid down in American and Australian orders, and strictly observed. All the troops arriving in Australia were kept on a suppressive dosage of atebrin for one month, which was discontinued under controlled conditions. All men developing malaria were admitted to hospital, and the full course of standard treatment with quinine, atebrin and plasmoquine was followed up with a further six weeks' administration of atebrin. In areas where vector mosquitoes were present, such as the Northern Territory and the coastal belt of Queensland, hospital wards housing patients with malaria were screened with wire. Notifications of malaria were required to state whether the disease was contracted in Australia or outside the mainland. During 1943, 135 soldiers contracted malaria believed to be due to local infections. These all took place in Queensland, and were of sporadic nature except in one outbreak of 18 cases at Sellheim, in a military camp through which men passed from New Guinea. About 60 to 70 per cent of these men in transit had previously had malaria, and many of them were sent to hospital. Here and in less important areas local transmission had occurred, and the vector was suspected to be *Anopheles annulipes*. Protective measures had not been complete, owing to the non-receipt of some essential supplies. Later in the year that irony attributed to fate was evident when another outbreak occurred at Canungra, which was a training area for jungle combat. The same mosquito was again suspect. In

addition there were 219 cases of infection in civilians contracted locally, most in Cairns. In none of these, or in others occurring in the Mossman shire in Queensland, was there any connection with the Services. Some local transmission of B.T. infection had possibly occurred in Brisbane, but the number of primary infections there was very small. In no instance was malignant malaria transmitted in Australia.

Cairns was now in 1943 a cause of even more anxiety than in 1942. It was agreed by the Allied forces that it was and would remain the most northerly of the important harbour bases for New Guinea and the north. Further, all troops arriving from New Guinea en route for the Atherton Tableland passed through there, and looked to Cairns for some at least of the amenities of a large centre. The yearly epidemics of B.T. in Cairns have already been described: it was now essential to control the large swamp areas on its outskirts. In July 1943 a conference was held between the U.S. Armed Services, the Australian Army and the Cairns City Council. All agreed to cooperate in carrying out the necessary control work, and the Queensland Government made a substantial contribution towards it. Mosquito breeding was free and took place even up to 2,000 feet above sea level in the Kuranda-Mareeba area and there was a heavy risk to the district if these mosquitoes became infected. It was most important to keep the military areas in the vicinity of Cairns free from infection, and to prevent transmission of malaria from servicemen to civilians in the Cairns district, which was already subject to seasonal epidemics, and was not a controlled area. The safety of Atherton Tableland above 2,000 feet contrasted sharply with Cairns. The United States forces also wished to develop the port facilities, which involved alterations in the swamp areas. After delays work was begun on the drainage scheme, though it took some time before the coordination of engineering schemes with anti-malarial requirements was effected. Up till June 1943 vigorous control work had been proceeding by army units, but the work could never have been finished without the help of the American engineer services and the Civil Construction Corps. In a general routine order the area north of 19° south latitude was proclaimed as "potentially malarious". This included Cairns, but not Townsville. Of course Cairns was actually malarious.

The effect of this proclamation was to stress the pressing danger not so much to the civil community, though the introduction of malignant malaria to Australia would have been deplorable, but to actual or potential battle stations. It drew attention too to the risk which had been incurred by the introduction of U.S., R.A.A.F. and R.A.N. personnel to these areas where the same vector and conditions lay in wait just as in New Guinea. For example, while serving in Ambon, a R.A.A.F. squadron had suppressed clinical malaria only by taking 10 grains of quinine a day: full precautions were impossible there. Most of the men were infected with malaria on their return, but their quinine was stopped in batches and treatment was carried out in those who then showed evidence of blood infection. Consternation had been caused to the medical advisers of the R.A.A.F. when squadrons were moved from New Guinea to Cairns and Darwin without warning.

No Australian troops were allowed to stay in Cairns and any contracting malaria in the district were promptly removed to the Tableland. The U.S.A. and other hospitals in the Cairns area took great care to prevent contact of vector and patient.

Sir Earle Page's report had stressed the importance of complete control of malaria on the mainland, and recommended the use of the Commonwealth Government authority to secure this. In particular he advised that the Government through the army and federal health authority take steps to implement a complete scheme for the drainage of Cairns, and also that power be sought to investigate and treat all civilians suffering from malaria. The Prime Minister, Mr Curtin, after obtaining the strongly favourable opinion of the army medical services, agreed to take the necessary steps. Accordingly, a National Security Regulation was proclaimed giving the power to the Director-General of Medical Services of the Australian Military Forces to carry out the examination of persons in a defined area in order to determine if they were infected with the malaria parasite and if necessary to prescribe treatment.

THE NORTHERN TERRITORY

In the Northern Territory even greater care was being taken to ensure that no extrinsic malaria was introduced which might blaze into an epidemic. Now that troops were being relieved from New Guinea this was all the more important. The occurrence of a localised outbreak at Katherine and Adelaide River outside the controlled areas showed again how the vastness of the country made general control impossible. The work of malaria control carried on by a keen but insufficient number was concentrated on the important areas. For instance, care was taken to keep a safe zone of a mile in radius round the hospital at Adelaide River. Aborigines were controlled by keeping them in compounds and areas free of mosquito breeding, and those used for labour were transported out and back between daylight and dark. It is not surprising that the army was criticised in some circles for these precautionary measures. Records were kept of all persons in the Territory who had been in a malarious area, and careful watch kept upon troop movements. Difficulties were sometimes encountered with "key personnel" arriving from malarious areas who were required to take suppressive atebrin for six months and have blood films examined regularly. Service units still needed to be carefully watched. For instance, an Australian air force squadron had been treating a number of their men for malaria contracted in New Guinea, but instead of evacuating all of them south had returned some to the unit. On one occasion the transfer of a body of malarialised troops was stopped at the eleventh hour through the vigilance of a member of the hygiene service. During the wet season anopheline breeding was slight because of the flushing effect of the heavy falls of rain experienced then and the rapid rise of the rivers. After the "wet" was over the lush growth of vegetation characteristic of many parts of the Northern Territory introduced fresh factors, and at this time breeding reached its peak. However, the principle was maintained in these

northern areas of Australia that control of the carrier was the unusual but quite practicable method of choice.

Meanwhile the already malarialised troops were stationed in safety at Atherton. Here the problem of malaria occurring in troops engaged in a war of movement did not arise, but that of controlling and treating relapses in returned troops had to be faced. Two general hospitals were stationed on the Atherton Tableland with the two divisions there undergoing rehabilitation and training, as well as other medical holding units and a convalescent depot. Now was the time to learn more about the medical problem of the hour. It was evident that relapses of benign tertian malaria were of great importance. It was desirable to discontinue suppressive drugs as soon as possible, yet important not to have military formations immobilised by men lost temporarily through relapses of malaria on the one hand and on the other hand to safeguard the men from risk of ill health due to post malarial anaemia and debility. It was also necessary to determine as accurately as possible the exact methods of action of the antimalarial agents available.

THE MALARIA RESEARCH UNIT AT CAIRNS

By June 1943 some 25,000 Australians had already contracted malaria in the South-West Pacific. It was imperative that further action should be based on accurate knowledge; therefore one of the most important steps of the war was taken in Australia in relation to malaria. The Commander-in-Chief, General Blamey, acting on the advice of the D.G.M.S., Major-General S. R. Burston, established the L.H.Q. Medical Research Unit at Cairns. The need for some such organisation solely devoted to the scientific investigation of malaria had been for some time apparent to the technical advisers of the Director-General. The plan evolved was really a cooperative project, but its original conception was due chiefly to Professor H. K. Ward (Professor of Bacteriology in the University of Sydney), Colonel E. V. Keogh (Director of Pathology and Hygiene) and Lieut-Colonel I. M. Mackerras. Colonel (later Brigadier) N. H. Fairley enthusiastically began the organisation and fulfilment of this project. With his long experience in tropical disease and especially in research he was chiefly responsible for the conspicuous success of this unit, and with his team of malariologists pressed home its teachings in the field. At Cairns the research unit had its own establishment as a military unit, and was attached to an Australian camp hospital. It was commanded by a physician with field experience of malaria, first Lieut-Colonel R. R. Andrew, later Lieut-Colonel C. R. B. Blackburn, and had a skilled staff of entomologists and pathologists. Associated with this unit was a research group attached to an Australian general hospital on the Atherton Tableland, thereby enabling therapeutic and other researches to be carried out independently. Similar investigations were also made at other hospitals at Atherton, and in New Guinea. By utilising also a convalescent depot farther inland, the staff could follow accurately the progress of men under observation. Special facilities were given the unit to ensure adequate supply of technical equip-

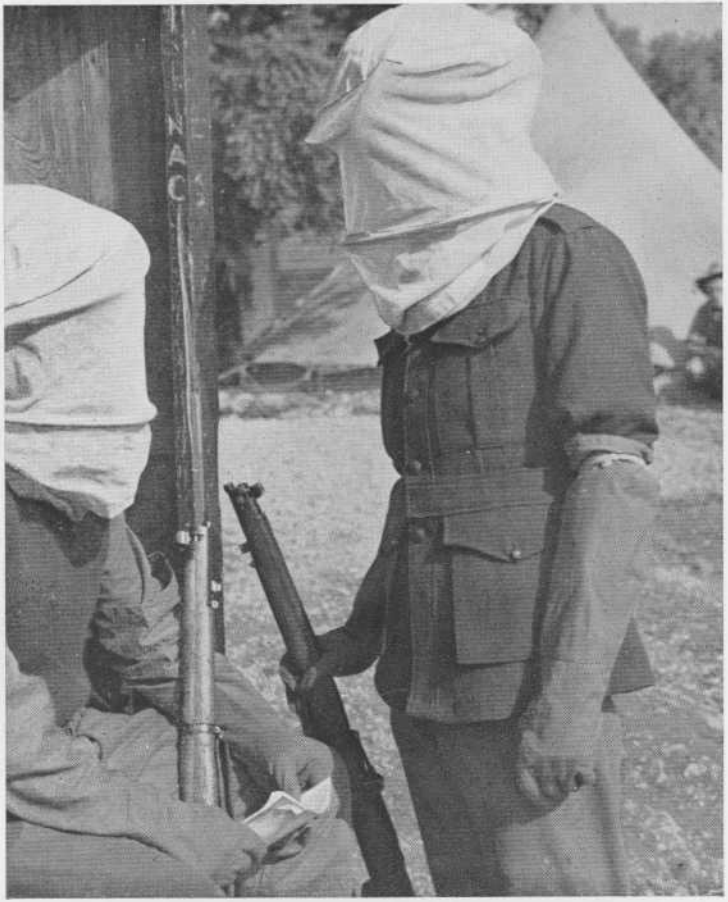


Malaria control—bivouac nets.



(Australian War Memorial)

Malaria research—collection of mosquito larvae for identification and research.



Malaria control—nets and gloves for sentries.

ment and stores, and also a special priority in transport. This latter was necessary to ensure the rapid transfer of patients and such biological material as mosquito larvae. The organisation also required the cooperation of the entomological services, and of physicians and pathologists in hospitals in New Guinea. The Commander-in-Chief approved of obtaining volunteers from the army for investigations on the action of drugs on experimentally produced malaria under a variety of environmental conditions.

The general plan followed in the research was to expose volunteers while taking anti-malarial drugs to bites of mosquitoes previously infected with malaria, and to study them throughout the incubation period of malaria. Later these men were sent to the hospital on the Atherton Tableland where further investigations were made to determine the success or otherwise of suppression. At Cairns mosquito-proofed wards were provided, and a special laboratory was prepared equipped for breeding and handling the mosquitoes. A special "humidity room" was made in which stocks of infected mosquitoes were kept. The mosquitoes used were anophelines bred from larvae and pupae collected in Queensland and New Guinea. During the early period of the work weather conditions were unusually dry and it was necessary to collect larvae from a wide area. Later a special collecting unit was stationed in New Guinea, which sent across to the mainland some 20,000 larvae a week by air. The entomological section of the unit under Major M. J. Mackerras was responsible for the collection of larvae and pupae, bred the adult mosquitoes from these and maintained the females, fed them on selected gametocyte carriers of malignant or benign tertian malaria and finally transmitted malaria to the volunteers by subjecting them to a known number of bites from mosquitoes. The sporozoite rate of these vectors was determined by dissection and examination of the salivary glands. Only the established vectors of malaria in Australia and New Guinea were used, *A. punctulatus typicus, A. punctulatus moluccensis* and *A. annulipes*. After some experience the *typicus* variation of *punctulatus* was found to survive best under laboratory conditions; it had a high average infection rate and bit most effectively, and was therefore used for most of the experimental transmission.

In collecting larvae it was necessary, especially in local areas, to reserve some breeding grounds from anti-malaria treatment, and care was necessary to ensure that general control of the area was not jeopardised. On emergence the adult mosquitoes were separated into species and kept in batches as large as convenient, each batch comprising as far as possible adults of the same age within a few days. They were fed on volunteer donors on the second day after emergence as nearly as possible, and separated again into experimental batches. Later feeds were given daily up to four to six days, different donors being used, but all carrying the same species of parasite.

Donors of blood were volunteers whose blood contained not less than one mature gametocyte of normal appearance to each ten fields of a thick film. Donors of B.T. infection were obtained on the Atherton Tableland,

but it was usually necessary to bring donors of M.T. from New Guinea. The volunteer recipients were drawn from convalescent depots in South Queensland at first. Only men who had never lived in malarious areas were suitable: they had to be physically fit and mentally stable, and free from venereal disease. Only men were accepted who had a record free of crime, and who had never had asthma or had not suffered from jaundice within the preceding year. Most of these men were of "B" class category, but for some aspects of the enquiry "A" class men were needed who were capable of undergoing strenuous exertion.

The clinical section undertook the medical care of the donors and recipients, supervised the administration of drugs under test and made accurate clinical study of the men's condition, of which full records were kept. Particular care was taken to observe accurately the diagnostic phenomena such as temperature, herpes, enlargement of the spleen and liver and other conditions such as anaemia and jaundice. If clinical malaria appeared treatment was carried out by various methods; the occurrence of relapses was recorded, and for this purpose each man was followed up carefully. Carriers of gametocytes were artificially produced at times by intermitting or modifying treatment so as to allow gametocyte production to proceed untrammelled after the primary trophozoite wave had subsided. Controls were always included in each group of volunteer recipients who received no anti-malarial drugs. These men were selected by lot. An incubation period of 23 days was chosen as a standard, after which men who had not acquired clinical malaria were sent to the hospital group at Atherton. Here, under Lieut-Colonel I. J. Wood, in charge of the medical division of the 2/2nd General Hospital, a special research ward was maintained, where the medical and nursing staffs were permanent so far as this was possible. Near the hospital full facilities were available for continued observation of men after suppressive treatment had been discontinued. The problems studied in this group were the method of action of anti-malarial drugs in volunteers infected by inoculation of blood containing trophozoites, and the investigation of men in whom malaria had not broken through after infection by sporozoites at Cairns. Observation was carried out over a period of at least five weeks after the cessation of suppressive treatment, during which a vigorous outdoor life was encouraged. Special investigations were also carried out to detect latent malaria and susceptibility and premunity to malarial infection. When a volunteer at the end of this final five weeks' period still failed to show any break through of malaria 200 cubic centimetres of his blood was injected intravenously into another compatible volunteer. Separate observations were made on infections with *Plasmodium falciparum* and *P. vivax* to elucidate the different mechanisms involved in the behaviour of these types in the human body. The possibility of a natural immunity to malarial parasites was investigated by injecting a determined number of parasites, from 100 to 800 million in infected blood, into volunteers who had failed to develop malaria after being subjected to mosquito bites.

The chief aim of the experiments was of course to test the efficacy of various anti-malarial drugs in suppressing or curing malaria in volunteers infected from mosquitoes. Several drugs were tested. Those first chosen were quinine, atebrin and the sulphonamides, especially in view of some evidence from animal experiments in America that sulphamerazine might act as a causal prophylactic. It was evident that if a drug could be discovered which truly would prevent malaria from obtaining a foothold at all, that is, with a lethal or inimical action on the sporozoite stage, the whole principle of malaria prevention would be immensely simplified. At the same time it was expected that sub-inoculation tests would give additional information about the erythrocytic and exo-erythrocytic cycles of the *vivax* and *falciparum* types of parasite.

In order to have accurate information concerning the effectiveness of the drugs used for the experiments blood concentrations were estimated in each case; a special study was also planned to show the building up of atebrin levels in the plasma during regular administration, and the receding of concentration after cessation of the drug. Finally an investigation was planned to show the influence of extraneous factors on the breaking through of malaria in men taking suppressive drugs. These factors were those encountered in jungle fighting, such as fatigue and cold, and in the case of aircrews in the air force, anoxia.

With this comprehensive programme the research organisation began its work; obviously its highly technical nature made quick results unlikely, and in the meantime another campaign was to be fought.

ADVANCES IN PROPHYLAXIS

In order to minimise sick wastage the Adjutant-General sent an instruction to all formations laying down the anti-malarial measures to be adopted by operational forces serving in malarious areas. This placed on the commander of a force the duty of examining all health hazards on entering a new area, and of using specially selected medical officers to make a preliminary survey of the area if circumstances permitted. It was further directed that a malariologist or equivalent officer should be attached for advisory purposes. Precautions were also outlined for the siting of camps, particularly in the region of native settlements, for the control of native labour, and for the limitation of breeding grounds for mosquitoes.

The official recognition of malariologists and the full organisation and utilisation of entomological services were two advances in the scientific equipment of the army that had far-reaching results. As told earlier, an entomological service was by now organised, and malariologists, found so valuable in tropical campaigns by the British Army, were appointed. A pool of malarial advisers was formed and attached to land headquarters for allotment to formations. Their functions included supervision of malaria control and advising on training of troops in the necessary measures.

Methods of training the troops had to be essentially practical. For instance, in one divisional area two creeks were used to create artificial breeding grounds which were demonstrated after the men had seen malarial

parasites under the microscope. In these areas track discipline and the pitching of tents were illustrated, and simple contour drainage was shown in a suitable boggy area. The jungle training area at Canungra was declared a malarious area for the purposes of training, and the most rigorous standards were exacted. Atebrin parades were part of the routine and were carried out under strict supervision. The use of mosquito repellent was ordered at the evening picture shows, and the Shell Company's film on malaria was shown. In order to bring the lessons of malaria control to the individual as a soldier an A.I.F. film on the subject was made. In April 1943 a special film unit was ready, and under the technical supervision of an experienced medical officer the taking of the film began. This was later completed and used for educational purposes. At the jungle training camp instructors in malaria control were also trained.

In the light of past experiences the general organisation of mosquito control was altered and improved. Mobile entomological sections were used to investigate field problems, of regional and general importance, to make field surveys, and to help the malariologists. Malaria control units allotted to formations were controlled by the malariologist or hygiene officer and, in addition to carrying out full local surveys, they planned and implemented control measures and trained anti-mosquito squads. If required, these units also undertook dengue control. Assistance was available in technical problems from the Universities of Sydney and Queensland and the Council for Scientific and Industrial Research. In the R.A.A.F. close contact was maintained with the army anti-malarial campaign and in New Guinea the principal medical officer, Wing Commander Fulton, and Squadron Leader J. Gunther, who had had tropical experience, greatly improved methods and discipline. A special handbook on malaria for medical officers was compiled and issued. For some time the supply organisation of the Air Board could not produce enough protective clothing to meet requirements in New Guinea, but where long trousers and long sleeved shirts were not available overalls were insisted on by official orders. The use of suppressives and repellent lotions was also supervised. An entomologist was appointed to carry out insect surveys and advise. Squadrons operating from Port Moresby kept their maintenance echelons there, so that only the aircrews operating from advanced flights near the front line or those forced down in combat ran serious risks of tropical disease.

In addition to these adjuncts to training special literature was circulated among those carrying responsibility, dealing with the incidence of malaria in the South-West Pacific and its prevention. At land headquarters a special Tropical Diseases Advisory Committee was formed to collect information from all sources concerning methods and supplies in order to integrate the measures adopted and to determine the quantities of materials required and available and the manner of their distribution. Drug supplies were reasonably satisfactory, and improved after the combined efforts of the commissions whose work has been referred to earlier.

Tests had been made of the new "Freon bombs"—insecticide dispensers —pyrethrum being used. These were small drums each containing the equivalent of one pound of pyrethrum flowers as 20 per cent concentrate in sesame oil dissolved in dichlor-difluoromethane, commercially known as "Freon" and used in refrigerators. A fine fog was projected by a gas pressure of 85 pounds per square inch and floating like smoke the contents of one bomb could kill all flies and mosquitoes in 100,000 cubic feet. They were found to be very effective, though rather extravagant and costly, and orders were placed for a supply. Dimethyl phthalate was being introduced as a mosquito repellent and efforts were being made to overcome difficulties and delays in its local manufacture.

Halfway through 1943 it was evident that although anxieties about medical supplies were not over, particularly those needed for the fight against malaria, there was every reason to hope that these medical munitions would be ready in sufficient quantities before the next campaign, which was expected to be undertaken in September.

In the course of studies of the position with regard to manpower a review of statistical methods and records was undertaken. Experience in the field had now shown that existing record systems did not disclose the true incidence of malaria or provide sufficient information. A research officer who was a trained actuary was seconded for the purpose of advising on statistical matters and in June 1943 an improved system was introduced. An administrative instruction detailing the alterations was circulated and the importance of this side of medical work in the field was stressed. An altered field medical card had an added page which provided a standard history sheet for cases of malaria. A new card was designed to give briefly the maximum data about diagnosed cases of malaria with the minimum labour on the part of medical officers. In this way information was gained about the probable source of infection, its type, clinical nature and degree of severity. For statistical purposes New Guinea was divided into various areas. Medical officers were reminded that unless such information was assembled, a number of important questions could not be answered such as the following: the relapse rate anticipated in B.T., the comparative results of various methods of treatment, the influence of re-infection on response to treatment, the comparative rates of infection in different areas, the influence of various military and environmental conditions on relapse rates, and the effect of delay in diagnosis and treatment on the end results of treatment. These problems were not merely of scientific importance; they concerned manpower both in operational areas and on the home front.

THE PROBLEM OF WASTAGE OF MEN

The incidence of tropical diseases had been, as has been shown, so high that the call made by malaria on manpower in reinforcements was the most serious of any. A considerable part of the reinforcement pool was perforce immobilised in hospital. During the early part of 1943 additional hospitals had been established in New Guinea. They provided for the

local treatment of men who could be returned to duty after a relatively brief period, thus saving wasteful evacuation to the mainland. It was best that such patients should be treated in New Guinea if possible, or alternatively in Queensland. The medical services had advised this for some time past, and Sir Earle Page in his report strongly supported it. The War Cabinet considered this question of manpower in 1943 in the light of the findings of a special sub-committee representing army and R.A.A.F. headquarters. With the air force the problem was not so acute: the force could be maintained at its strength in New Guinea, although its actual malarial rate was very high and comprised 89 per cent of the total casualties, but the army's larger demands in operational areas and its proportionately greater malarial risks involved great inroads on manpower. For the quarter ending 23rd January 1943 tropical disease had caused 14,011 casualties as against 4,137 battle casualties.

In order to maintain the size of the existing force for offensive operations, it would be necessary to review the order of battle, as reinforcements might have to be drawn from other sources. The medical services in reporting to the Cabinet hoped that, with the additional measures taken, the improved equipment and supplies and the heightened understanding and better anti-malarial discipline in the forces, operations could be undertaken in hyperendemic areas at a lower cost from illness than hitherto. Since malaria was responsible for about 90 per cent of the sick wastage due to tropical disease, the problem was largely one of control of malaria, and though it was believed on good grounds that the Japanese losses had been much higher than the Australian and their control measures much inferior, this gave no cause for over-optimism. Rumour was current at one time that the Japanese were immune to malaria, but this was completely untrue. Intelligence investigations revealed that such protective measures as they adopted were complicated and inefficient. It was most regrettable, and in fact a serious break of security that information was at this time published and broadcast in Australia concerning the work of Australian malarial control units and the use of modern methods of treatment and prevention of malaria. On the basis of experience in Milne Bay, even with improved facilities and methods, a rising malarial rate might be expected after three months of active fighting. It was hoped nevertheless that these heavy losses would not be repeated, for at Milne Bay the malarial rate of loss was 5 per cent of the force in the first month, and rose by 5 per cent each month up to 25 per cent in the fifth month. A maximum rate of 15 per cent for general sickness seemed more likely. The army sub-committee finally reported to the Cabinet that out of a military commitment of half a million a striking force of not more than 95,000 could be maintained in active operations in hyperendemic malarious areas only if large deficiencies were made good, if reinforcements were maintained and if no abnormal casualty rate was experienced.

The question of supplies was also considered. Enough quinine was held for immediate purposes, though more was needed. Quinine was now being reserved for therapeutic treatment only and enough atebrin was held to

keep the striking force on suppressive treatment for six months. More atebrin was expected to arrive shortly. Plasmoquine was held in quantities sufficient for present needs. The position about mosquito nets was still not satisfactory, as supplies promised had not yet reached Australia in May 1943. The Combined Advisory Committee on Tropical Medicine advised General MacArthur of these deficiencies and also recommended that the fulfilment of these orders should be expedited, and that replacements of nets for Allied forces in the Pacific areas should be increased, owing to the heavy wear and tear. As one of the earlier troubles about supplies had been their distribution to forward areas, a special instruction was issued by the Army Director of Supply and Transport to ensure the prompt despatch of anti-malarial stores. All these were specifically and indelibly branded with a description of their contents, indicating plainly that they were intended for anti-malarial use only. Where practicable important supplies were placed in the charge of a responsible conductor. So the next campaign was faced with the hope that the plasmodium of malaria would be overcome as well as the Japanese.

At the end of the period of preparation the malarial position in New Guinea was fairly satisfactory, but reports from some areas could be read as cautionary tales. The forces operating between Wau and Mubo showed reasonable infection rates. At the end of August their rate for all attacks was 9.5 per 1,000, but there was difficulty in getting figures from forward areas in country with such restricted communications. The rate for the whole of New Guinea was roughly half this local rate. In some other limited areas the position was less satisfactory. For example, a unit in the Buna-Oro Bay area showed heavy wastage due to fresh infections.

The position with clothing was still not quite satisfactory, but was improving. Some anomalies created discontent, as when senior staff officers visiting New Guinea appeared in shorts, or when new consolidated orders on dress permitted the wearing of shorts. As a matter of fact, though the malarial rate of Moresby was much on a par with other controlled areas the chief reason for restrictions there was the force of example.

In passing some reference may be made to anti-malarial discipline in hospitals and other medical units. The potential danger of a large infected pool of malarial patients in hospital was evident, and General MacArthur had ordered some time before this that all hospitals in malarious areas on the mainland should have wards protected with wire screening. In New Guinea this was not possible in the field, and even in base units screening was impossible on the scale necessary, at least in Australian hospitals, for the material simply could not be obtained. However, care and discipline minimised this risk. In over twelve months the 2/9th Australian General Hospital had admitted 24,000 patients, a great proportion of whom had malaria. Only two wards were screened, but nets were used continuously, patients being kept under them from dusk to dawn. Where exposure of a patient was necessary other precautions were taken. Only one case of malaria had occurred in the staff of this hospital, though infections had occurred in other units within half a mile of the site.

IN THE MARKHAM AND RAMU VALLEYS

On 4th September 1943 new operations began with the landing of the 9th Australian Division on the shore of the Huon Gulf with Lae as their objective. The next day American paratroops, Australian paratroop artillery and Australian engineers and pioneers took Nadzab, thus enabling the 7th Australian Division to move by air into the Markham Valley. A little over a week later the Australians had captured Salamaua and Lae, and a few weeks after this had taken Finschhafen, and Dumpu in the Ramu Valley. Further heavy fighting took place on the coast, and by the end of November 1943 the Japanese had been driven from the hilly country where they had taken up positions. By 10th February 1944 Australian troops had linked up with the Americans at Saidor, who had made a by-pass movement and established there earlier. Thence the drive continued up the coast and by the end of April Madang and Alexishafen had fallen.

The medical significance of these successful operations should be noted. To begin with, both the Markham and Ramu Valleys were highly malarious: so too were the coastal strongholds of the Japanese. Here and in the hills the enemy was dug in, and in coastal areas like Lae had suffered heavy malarial casualties. The advancing forces had to occupy areas defiled by the retreating enemy, and infested with heavily infected mosquitoes. The malarial experience of the divisions engaged varied. The 9th Division had had no real experience of malaria in operations, and only a small number of the troops had contracted malaria in Syria where they had acted as a garrison force. Their physical condition was excellent. The 4th Australian Infantry Brigade had been in Milne Bay, and had profited by the sound anti-malarial training of the 5th Division. Another brigade group, the 8th, only arrived in the later stages and had not had previous experience in a malarious area. The 7th Division had had operational experience in malarious country in Syria, and had been over the Owen Stanley Ranges into the Sanananda-Buna-Gona area where it suffered heavily from malaria. Since then the division had been well rehabilitated and reinforced.

It was disappointing to encounter a high malarial rate which at its peak was comparable with that experienced in the earlier campaigns. By December 1943 despite all endeavours, the position was again serious. Ten weeks after action began the malarial rate for all troops stationed in New Guinea, which of course included large numbers of men in base areas, was 17.2 per 1,000 per week, that is, 890 per 1,000 per year. The overall rate for the operational troops on the Huon Peninsula (some 30,000 men) was 55.3 per 1,000 per week (2,875 per 1,000 per year). The rate for the 7th Division in the highly malarious Markham and Ramu Valleys was 93 per 1,000 per week (4,840 per 1,000 per year). This peak coincided with the period of severest fighting in which most battle casualties were received. During this ten weeks 90 per cent of the total sickness casualties were due to malaria in the forward troops of the 7th Division, and 60 per cent in the 9th Division.

This result was a setback; both divisions had experienced a true malarial epidemic of the type familiar in hyperendemic areas where non-immunes had failed to take adequate precautions. However, the position was not so serious as the figures at first suggested. To begin with, the figures for the 7th Division were probably overstated owing to difficulties in diagnosis. Dengue fever was prevalent, and on reviewing medical affairs of the campaign later, medical administrators who saw conditions on the spot concluded that numbers of men with dengue had been classed as having unconfirmed malaria. It was evident, however, that greater efforts to reduce adult mosquitoes and minimise biting during the day would have decreased the wastage of men. The general health and nutrition of the troops were better, rations had greatly improved and, in spite of the high peak levels in the sickness statistics, the incidence of malaria was lower than in the Buna campaign. More adequate provisions for treatment in medical units lessened the bad effect of attacks of primary fever on health, and more control units were available with more and better equipment. Though some of the fighting was intense and hard, the severity and duration of combat were less, and reinforcements were available, at least to most of the formations. Transport conditions were also greatly improved, with a favourable effect on supplies and evacuation of the sick. Air evacuation had now become more firmly established and organised, thus lessening the strain on medical units in the forward areas and facilitating treatment. In the Ramu Valley at one period the strain on medical holding units became severe since the call on their accommodation had surpassed expectation.

This great wastage in the 7th Division called for some strong measures, and fortunately by this time, December 1943, the work of the research unit at Cairns was sufficiently advanced to give the answer. Experiments on suppressive drugs had shown that experimentally produced malaria would not break through to cause a clinical attack while 0.6 to 0.7 gramme atebrin a week was faithfully taken. The official dose was already 0.6 gramme a week, therefore it appeared that most of the men were not actually taking this full amount. To ensure that they received a full suppressive dose the weekly rate was doubled: acting on medical advice and with the concurrence of General MacArthur the 7th Division troops were ordered to take 1.2 grammes of atebrin every week. During the next month the fighting was less severe, and the more heavily infected component units of the division were assembled in rear areas to await return to Australia. Even allowing for these factors the difference in the malarial rate was striking: a weekly rate of 43.7 per 1,000 during December became in January one of 14.3 per 1,000, in other words, the annual rate of 2,270 per 1,000 fell to 740 per 1,000.

The effect of these and similar factors in lowering the fighting capacity of a formation engaged in operational activities is well illustrated in a contrast between 9th Division and 4th Infantry Brigade at the end of 1943. The former had not been in New Guinea before, the latter had been in Milne Bay eight months. Their periods of severe fighting on this front were relatively six weeks and two weeks, but the division had

received 3,400 reinforcements in five months, whereas the brigade had received none. Their malarial wastages were the same, 44 per cent of the division, including reinforcements, and 43 per cent of the brigade. The 9th Division, with its advantages of reinforcements and starting its task fresh from training, was still an efficient fighting force a month after active operations had concluded. The 4th Brigade, coming to its new role after a considerable period of tropical service, had its three battalions reduced from 1,658 to 952 men, and many of these were tired and not fit for further hard fighting without a rest. One comforting fact emerged from an analysis of the malarial casualties that relapses in men who had been infected during the last campaign were not increased in number or frequency by the strain of operations. The rate of relapsing attacks remained steady at about 3.5 per 1,000 per week, which was regarded as a satisfactory figure.

THE LESSONS OF 1943-1944

Turning to the factors more directly concerned with the incidence of malarial infection we find that a number of points become clear. The staging areas for troops committed to an operational task in the tropics are of importance; ideally they should carry a low malarial risk and be well controlled. This does not mean, however, that men cannot contract malaria there; it is a matter of discipline. In some areas dress discipline was still poor, men bathed after dusk and failed to carry out other precautions such as the use of repellent. Slackness during the day had unfortunate results, as dengue was prevalent in these areas. In the areas of occupation there is no doubt that the Japanese had been severely attacked by malaria. As a rule the objectives were taken quickly in these actions; this lessened the risk, for although there was an abundance of infected mosquitoes on the wing at the time of each assault, the time elapsing before reasonable control was begun and made effective was brief. This last condition was not always fulfilled. The malaria control under the command of the 7th Division was not employed in the operational area until nearly two months after the campaign had begun.

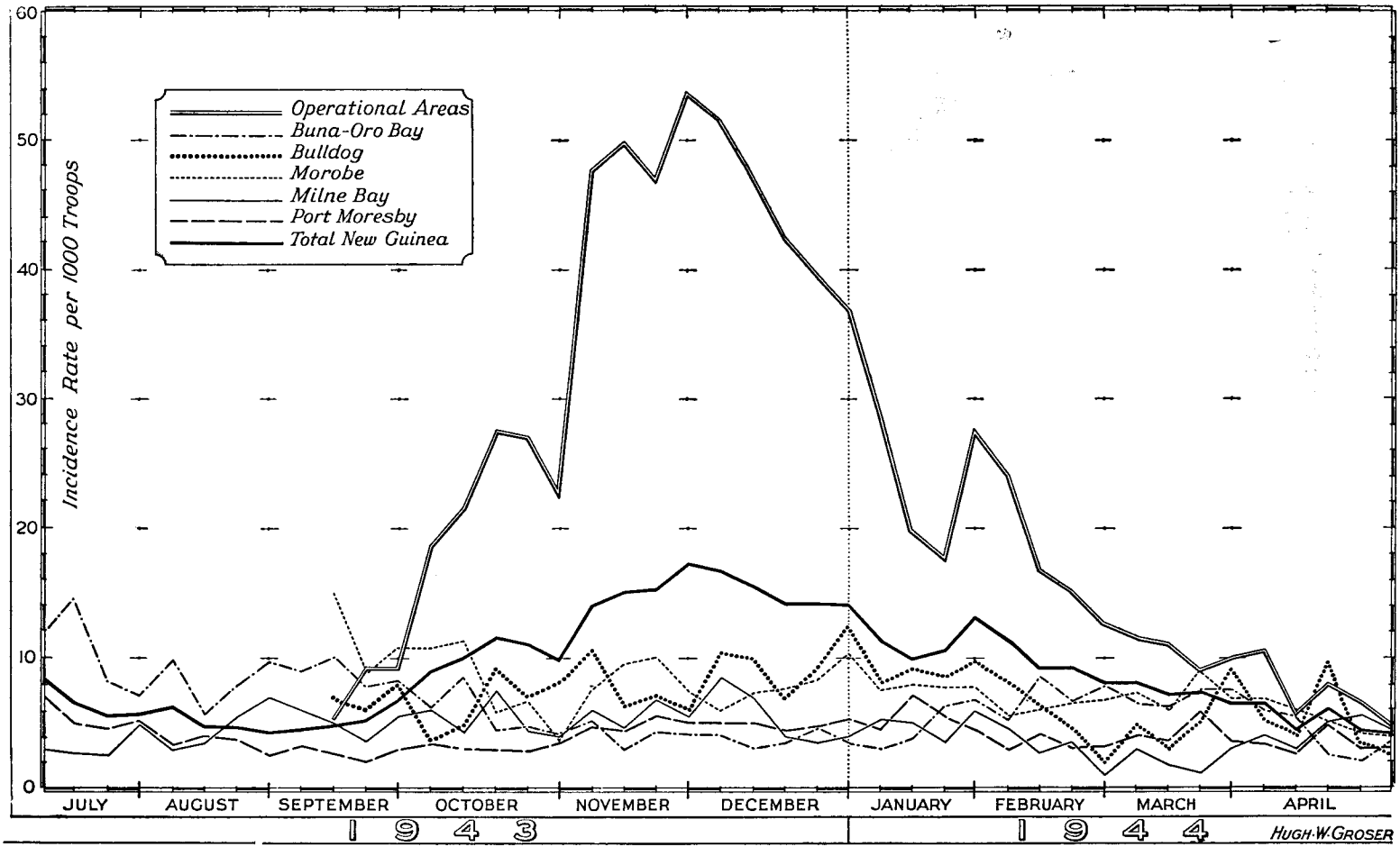
Once areas were occupied the malarial risk was dependent on the life of the mosquito, a factor varying with climatic conditions, the intensity of breeding, and the supply of gametocyte carriers. The last mentioned could come from neighbouring Japanese troops, or native population or from the Australian troops themselves. With regard to the last source of parasites, medical units sometimes created more risk than desirable because they did not always have enough nets for the number of patients they held, and the units sending the patients often did not send nets with them. Natives usually retired to the hills, but carriers were, under operational conditions, quartered near the troops and the suggestion was made that they should be treated with plasmoquine.

Anti-malarial supplies during operations were usually adequate, but atebrin did not always arrive regularly, a few packages being lost or mislaid during the early stages of the campaign. Freon pyrethrum "bombs" were used, but up to that time their even distribution and training in their

use were not satisfactory. Sprays were not always on hand when wanted, and difficulty was experienced at times in bringing them forward from rear areas where they had been left. The work of the malaria control units was good. Lae and Finschhafen could not have so quickly been used as bases had they not been made safe by skilful and well organised control work.

In several such instances the value of possessing bases and forward bases with low malarial risks was evident. This was all the more important with units whose malarial discipline was not of very high grade. One battalion in the coastal area had 175 fresh infections of malaria out of 600 men within ten days in a malarious area, another battalion similarly lost 100 out of 850 in a week. The standard of malarial discipline varied greatly among units; it became apparent that it was necessary that a responsible officer should each night notify to the formation headquarters that all malarial precautions had been taken. There was no doubt in the minds of medical administrators on the spot that the use of repellent lotion was often neglected, and that failures to take atebrin one or two nights a week were common. Mosquito nets were often found discarded along the way. There were several faults. The nets were often of unsuitable type and quality, insufficient supervision was imposed, and deficiencies were not promptly made good. Worst of all, men were allowed to occupy captured areas for as long as a week or ten days without nets to exclude the throng of infected mosquitoes. Enquiry showed that in the Lae operations 90 per cent of a number of men questioned had not used nets for some period, which in the aggregate was usually part of a week. Only two-thirds of these men used repellent all the time, though on the whole the new repellent was well used and appreciated by the troops. Unfortunately in many dangerous areas in New Guinea there were few pest mosquitoes whose noise and painful bites gave warning of their presence, whereas the silent anopheline often did its damage unnoticed.

These breaks in discipline and lack of appreciation of the importance of ordered routines were not necessary and that they could be overcome was proved by the 15th Australian Infantry Brigade. During the first week in January, following the heavy malarial losses of the 7th Division in the Ramu Valley, this brigade was brought in to drive up to Madang on the coast. It had already been engaged during the five preceding months in the Wau-Salamaua area. Recognising the risks involved, Brigadier Hammer, the commander, and members of his staff had evolved an organisation for the enforcement of anti-malarial precautions. The essence of this was that the responsibility for carrying out these procedures was cast directly upon the unit commanders and sub-unit commanders, who daily informed headquarters that all personal methods of protection had been carried out, including the taking of atebrin. During the first quarter of 1944 this brigade was engaged over a wide area in the operations which resulted in the capture of Madang and Alexishafen. Its average malarial rate was 7.6 per 1,000 per week (395 per 1,000 per year). This rate was no higher than that attained at Lae after control had been instituted.



Incidence of malaria in New Guinea and in dissected areas in 1943-1944.

and was easily the best figure achieved by any formation engaged in this campaign. It was most heartening to the medical services to see this practical demonstration of control, and to read the commander's description of the precautions laid down by the medical authorities as "sound and practicable" measures which "can be readily accepted and put into operation by all commanders". The routines established in this brigade had a potent influence in determining a general disciplinary standard for the future.

By April 1944 this twofold campaign was over, and there remained the tasks of clearing up the areas and later pressing farther along the coast. But for the present the objectives had been gained and the time was come for appraisal and criticism. As pointed out above, the impact of malaria on these forces was much less severe than at Milne Bay and Buna-Gona, and, though in need of rest and rehabilitation, the troops were not hit hard physically. The difference between the incidence of malaria in quiet areas and in those where fighting was going on was again apparent. This was exemplified in other areas also. For instance army and R.A.A.F. forces in Merauke and Tanah Merah were in highly malarious areas, and the rising rates gave concern in early 1944, approaching 1,000 per 1,000 per year. Here there were local difficulties such as a heavily infected native population, but these were overcome to some extent by improved control. Had action taken place there at this time, there is no doubt that losses would have been serious.

THE ATHERTON CONFERENCE ON MALARIA

On June 12th and 13th an important conference was held at Atherton to discuss the position. Malaria had proved as dangerous an enemy as ever, but there were two important weapons to hand, one that of military discipline, the other that of science, for by this time important conclusions had been reached in the research unit at Cairns. The Atherton conference on "Prevention of Disease in Warfare" was held under the chairmanship of Lieut-General V. A. H. Sturdee, then G.O.C. First Australian Army. The Adjutant-General, Major-General C. E. M. Lloyd, in opening proceedings pointed out that during the period September 1943 to the end of February 1944 there were 3,140 battle casualties in an average strength of 98,050 men, and 47,534 were evacuated sick. Brigadier Fairley described the results obtained from research on anti-malarial drugs. The work of the research unit will be dealt with later in greater detail; the most important finding was that concerning atebrin. It had been found that volunteers proved to be inoculated with malaria infection would remain well without the onset of malarial fever while they took 0.1 gramme of atebrin with complete regularity. Once an adequate concentration in the blood was built up, and while it was maintained, these volunteers could engage in laborious occupations and be submitted to fatigue or to exposure to extremes of temperature without any break-through of malaria. Further such a regimen would not only suppress benign tertian while atebrin was taken, but it would cure malignant tertian. If the experimental results held

good in the field it was thus possible to keep a fighting force free from overt malaria by maintaining a blood concentration of atebrin such as could be obtained by the regular taking of 0.7 gramme a week. Four weeks after such a force was returned from a malarious to a safe area the risk of malignant malaria was small, and the use of atebrin could then be discontinued. Relapses of benign tertian were sure to occur, and their percentage would be some indication of the lapses in personal measures of protection. The incidence of benign tertian would of course depend partly upon the efficiency of external control methods. One most important conclusion came from the unexpected finding that malignant malaria was cured by the taking of an invariable suppressive dose; it was that the faithful following of this routine would abolish blackwater fever and reduce the death rate from malaria to zero. Major J. C. English, the malariologist of the I Australian Corps, described fully the practicable methods of prevention of malaria in the field, and Major C. E. Cook described the measures by which intestinal diseases such as dysentery and cholera could be prevented. Major-General S. R. Burston, D.G.M.S., summed up the discussion by pointing out to the divisional and brigade commanders that the measures which would prevent malarial wastage were their responsibility, and ended with the historic words, "Gentlemen, the ball is now in your court".

This conference was a milestone along the way of malaria control, and from it sprang an extensive and intensive campaign of education by all available methods. Operations were planned for the latter part of 1944 and 1945, and in preparation for these it was essential that all ranks be acquainted with the necessary measures. Responsibility also rested with all ranks, but close and constant supervision was necessary as the lessons of past campaigns had shown. From early in 1944 the principle had been adopted to which reference has been made before, that the responsibility for carrying out the measures of malaria control rested with commanders and sub-commanders of units. There is a vast difference between the tacit and the actual implicit acceptance of responsibility in the army and other armed forces. This was now not a matter of personal keenness, it was an obligation of duty, and as such, neglect carried appropriately severe penalties.

FURTHER ADVANCES IN MALARIA CONTROL

The Atherton discussion emphasised the vital importance of the maintenance of suppression, steady and unvarying from day to day, and of the close attention to every detail of control. Months before General Burston had said that "it must be ensured that every soldier carries a month's supply of atebrin tablets as a reserve, and loss of these tablets should be regarded as seriously as the loss of a rifle". He further advised that stockinet nets should be withdrawn from units actively engaged in operations and replaced by the lighter and less absorbent bobbinet nets. These should be discarded by the soldiers only on the order of the unit commander, who should take the responsibility for the decision. Such dis-

carded nets should be protected from the weather if possible and kept in an accessible place.

During 1944 another advance was made in mosquito control by the introduction of D.D.T. (Dichloro-diphenyl-trichloroethane). This substance had been under investigation since 1943. This new insecticide was effective both as a killer of adult mosquitoes and their larvae, and its remarkable potency even in incredibly high dilutions made its use possible by aerial spraying. In May limited quantities were available for field trial with a view to using it for the spraying of areas immediately after a landing. There was an immense demand for D.D.T. in America and England, and production in Australia was then only in the pilot plant stage. There was good reason to hope that when further active operations began over a wide area in November this important aid to mosquito control would be ready for full use. By July spraying of D.D.T. from aircraft was accepted overseas as well past the experimental stage, and its efficacy in destroying many varieties of insects, including the louse vector of epidemic typhus made it one of the great discoveries of the war period. An early trial of D.D.T. in Alexishafen soon after its capture showed how rapidly control could be effected and how the work of control units was likely to be revolutionised.

Meanwhile Australian troops were holding the ground gained in north-eastern New Guinea and steadily pressing on up the coast, where Hansa Bay was occupied in June 1944. In the first quarter of 1944 there had been 11,074 cases of malaria out of an average strength of 91,000 men; in the second quarter out of 70,000 men there were 3,261. The rate per 1,000 per week had thus fallen from 9.3 to 3.6. During the next quarter it fell to 1.5 per 1,000 per week. Of course conditions in operational areas had become much quieter, but the improvement was encouraging.

Malaria control units were re-organised into three different types, according to requirements, and a special tropical scale was provided for jungle operations. Intensive training of officers and men for this work proceeded, and using the standard methods now proved effective the infested areas of New Guinea were cleared up and kept under control. Bad areas like Lae, full of mosquitoes at the time of its capture, were made as safe as Moresby. Entomological surveys and experimental work supplemented these methods and, although 1944 provided less action than the preceding period, there were a number of proving grounds, such as the operations from the Ramu to Bogadjim, and from Finschhafen to Hansa Bay and the mouth of the Sepik River. In the forward bases of New Guinea then there was evidence of a general lowering of the malarial rate, and it was demonstrated too, that malaria-free bases could be established from which fresh advances could be made.

In November 1944 the combined rate for troops in both base and forward troops in New Guinea was 26 per 1,000 *per annum,* whereas a year earlier it had been 740 per 1,000.

Meanwhile the 7th and 9th Divisions, so severely attacked by malaria in the recent campaigns, had returned to Australia between February and

April 1944. What was to happen there while they rested and underwent further training? To what extent would recurrent malaria attack these forces and how would their experiences affect their fighting efficiency? By this time knowledge gained in the field and in the medical research unit could forecast that a great wave of benign tertian malaria would sweep over the resting divisions, and that malignant malaria would occur in small and rapidly disappearing numbers owing to the curative action of suppressive atebrin. With the arrival of the 7th and 9th Divisions in Queensland the total rates of relapsing malaria did in fact rise promptly after the troops had ceased to take atebrin. The wave of B.T. reached a peak between June and August 1944 and then rapidly fell so that by November the malarial rates of these troops and those then operating in New Guinea were comparable and satisfactorily low. The physical condition of the troops soon reached a high pitch and prompt and adequate treatment dealt with the relapses. Although the malarial figures for the campaign had been disappointing, the impact of the disease on the force was much less severe than before, and after due rest the divisions committed to operational roles in 1944-1945 were fit and ready.

During the third quarter of 1944 more rigorous measures of hygienic training were adopted, by the use of visual and practical educational methods, and insistence on strict invariable routines. The principles enunciated above, whereby commanders assumed the full responsibility for the carrying out of preventive measures, were put into effect. "It was not only a question of organisation" as one malariologist said, "our results were better because we all knew more".

RESULTS OF MEDICAL RESEARCH

A digression must now be made to describe what scientific advances had been made. The initial programme laid down for the Cairns medical research unit has been outlined earlier, and the methods employed. The first task undertaken was a comparison of the value of various drugs in the suppression of malaria.

Reliable methods were established of producing experimental malaria either by the bites of infected mosquitoes or by the inoculation of infected blood, that is producing either sporozoite-induced or trophozoite-induced disease. Methods of estimating the concentration of anti-malarial drugs were elaborated. Fantl's modification of Werner's method was used for the sulphonamides, and in later estimates Marshall's method. A laboratory of the U.S.A. medical corps helped in the early stages in carrying out the plasma-atebrin estimations, until a Coleman photo-fluorimeter was obtained which was used for quinine and atebrin.

The first drugs to be tested were the sulphonamides. Reports had been received earlier of the effectiveness of sulphamerazine in particular as a prophylactic in bird malaria and one field test in West Africa also seemed promising. For some years it had been known that some of the earliest produced members of the group acted on the parasites circulating in the blood, and while it did not seem likely that the long wished for causal

prophylactic would be of one of this series the possibility had to be explored. Sulphadiazine, sulphamerazine and sulphamezathine were tested in daily doses of 1.0 gramme. Sulphamerazine showed the highest and best concentrations in the plasma, and maintained a higher and more constant blood level, and was relatively free from toxic manifestations. For these reasons it was selected for manufacture in Australia. In the malarial experiments with each drug the same broad lines were followed. Volunteers were exposed to infective bites carrying *Plasmodium falciparum* and *P. vivax* in separate series. The number of bites varied in different experiments, in most instances being higher with *vivax* species than *falciparum.* Some of the volunteers acted as controls and received no drug: they invariably developed overt malaria within the usual incubation period. Sub-inoculation experiments were carried out to find out if the men in whom malaria had been successfully suppressed and who had not demonstrable parasites in their blood at the time could transmit malaria. This reinforced the clinical evidence of successful suppression. Other sub-inoculations on these same volunteers after the experiment was over were made with blood containing the same species of parasite to prove that the men were susceptible to malaria. Thus a successful experiment established that a drug had the power to suppress malaria of a known type in men proved to be susceptible to infection by that type. As time went on the value of sub-inoculation to demonstrate blood infections after given periods was worked out more in detail. Observations on the sulphonamides proved that in M.T. these drugs can kill schizonts in the blood, provided they are given over a sufficiently long period. In practically all instances the disease was successfully suppressed. In B.T. the results were much less favourable. In both sporozoite and trophozoite transmitted malaria these drugs exerted a very slight suppressive action. Therefore it was clear that their value was limited.

When atebrin was similarly tested the results were surprising. In fact the hopes for sulphamerazine at the time led the experimenters to try the effect of atebrin alone and of atebrin in combination with sulpha drugs. Two groups of volunteers were tested, one receiving 0.6 or 0.7 gramme atebrin weekly, and the other 0.6 gramme atebrin and 1.0 gramme sulphamerazine daily.[8] The administration of atebrin was begun from 22 to 46 days before the beginning of the experiment in order to ensure maximum concentration of the drug in the plasma; with sulphamerazine a period of two days was sufficient. The drugs were continued for 23 days after the period of exposure. Fifty volunteers were used in the experiments on M.T., half receiving infective bites and half sub-inoculations—no infections occurred. Sub-inoculations showed that the blood some 7 to 9 days after exposure was infective in spite of the fact that parasites were not demonstrable. Later sub-inoculations proved that the infections had been cured with the continued suppressive dose of atebrin. The tests of B.T. showed that atebrin prevented the disease from breaking through, that is, from

[8] Further details and figures are available in Fairley's article published in May 1945 in *Transactions of the Royal Society of Tropical Medicine and Hygiene.*

becoming overt, but in every case after discontinuing the drug the volunteers developed clinical malaria with demonstrable parasites in the blood. During the administration of the drug no parasites could be found in the blood, but in a few men in each group tested mild symptoms of disturbance occurred, including transient slight fever, headache and abdominal discomfort, sometimes associated with tenderness and enlargements of the spleen or liver. Other groups were tested to find the action of atebrin alone or with sulphamerazine on B.T. produced by blood inoculation, that is, trophozoite-produced B.T. The disease was completely suppressed in every instance and, what is even more interesting, cure was effected, as it could not be transmitted by further blood inoculation, no parasites appeared in the blood and no relapses followed. In these series of observations the action of atebrin was so positive that no advantage could be detected by adding sulphamerazine. Concentrations of the drugs were found to be maintained well: the group receiving atebrin only showed an average mean of 21.3 microgrammes per litre, while the group receiving atebrin and sulphamerazine showed an average mean of 23.1 microgramme per litre.

These results indicated that atebrin was a reliable and effective suppressive when taken in doses of 0.6 gramme a week. This dose would suppress B.T., and would suppress and cure M.T. Sporozoite-transmitted B.T. was not cured by a suppressive dose, but the trophozoite-produced form was cured.

Further experiments were now indicated. It was evidently highly desirable to try to reproduce the conditions under which men acquired malaria in the field, and also to ascertain what would be the effect of smaller doses of atebrin, such as were already being given for suppression in areas where malaria was endemic only to a moderate extent. In the previous experiments, as above described, a number of infective bites, ranging from ten to over twenty, had been received by the volunteers over a period of one week or less. It was now planned to carry out a "field type" of experiment, in which the men were subjected to the biting of infected mosquitoes repeatedly over a period of months. As prolonged exposure to infection was found to produce mixed infections with M.T. and B.T. under jungle conditions in New Guinea, both *falciparum* and *vivax* types of parasite were allowed to infect these men. The universal experience had been that if men broke down and showed signs of clinical malaria while exposed to prolonged risk and while taking atebrin only *P. falciparum* was found in the blood. On the other hand, when troops who had been exposed to such risks of infection resumed static conditions or were returned to Australia, the cessation of suppressive atebrin was frequently followed by relapses, which were predominantly due to *P. vivax.*

Over fifty volunteers were subjected to this experiment. The men were divided into three groups who received 0.1 gramme atebrin daily, 0.1 gramme atebrin and 0.1 gramme of sulphamerazine daily, and 0.2 gramme atebrin daily respectively. Drug administration was begun at appropriate intervals before exposure as before, and continued throughout the period

of exposure and for 28 to 34 days after. These volunteers were exposed to heavy infection, in fact to much heavier infection than could occur under service conditions. Some volunteers received 200 infective bites at Cairns in two months; to parallel this in the field it would be necessary to be bitten by impossibly huge numbers of mosquitoes, since the sporozoite rate of average vectors is reckoned as high if it reaches 3 per cent, and is probably nearer 1 per cent in the average of mosquitoes in the jungle where the troops fought. Anophelines of species *punctulatus typicus* were used, and were infected from carriers showing a high gametocyte count in the blood. Daily dissections were made to ensure that the salivary glands were heavily infected; as a rule more heavily than would be expected under ordinary conditions. The number of infective bites varied from two to thirty-five each session, and during the period of exposure which was from 49 to 92 days, there were 10 to 20 sessions. As a rule the exposure to *falciparum* was twice that to *vivax*. A control volunteer was used for each new batch of mosquitoes. During the period of experiment, some three to four months, each volunteer's blood was thoroughly searched for parasites; only in 4 out of 55 men were they found. In 2 of these the plasma atebrin level was only 10 to 12 microgrammes per litre at the time, and in the other 2 it was inordinately high on the following day, 50 microgrammes in one instance, 74 microgrammes in the other. In the latter 2 there is no doubt that evasion of atebrin was followed by the taking of a massive dose. Only one other instance of atebrin evasion was found. In not one man of these 55 did malaria break through, a break-through being defined as having occurred if there was fever of over 100°F. with parasites present in the blood, causing illness sufficient to make the patient go to bed. The health of these volunteers was excellent, and was interrupted by only a few minor disorders.

It is interesting that 15 of the men had minor indisposition of transient nature, with a temperature over 100°F. Such findings are not uncommon in the tropics, apart from overt malaria, and it must be remembered that Cairns has a tropical climate, and that much of this work was carried out during hot weather. It may be remarked, however, though the numbers are probably too small to be statistically significant, that more of these transient disturbances occurred in men taking 0.1 gramme of atebrin daily than those taking 0.2 gramme; a palpable spleen and liver were also more frequently observed amongst them. Slight fall in the red blood cell count was noticed during the period of the experiment and slight lowering of the haemoglobin value, the average decrease of the latter being 1.1 gramme per 100 cubic centimetres. The average arithmetic mean level of atebrin in the plasma of men taking 0.1 gramme daily was 22.9 microgrammes per millilitre, and this was assumed to be adequate to prevent the occurrence of malarial fever. Individual plasma levels were subject to considerable variation. A dosage of 0.2 gramme daily was found to be superior to 0.1 gramme, the average mean plasma level being 44.2 microgrammes per litre. The average minimum plasma content for 0.1 gramme dosage was 12.8 microgrammes, whereas that for 0.2 gramme dosage

was 27.3. After atebrin had been suspended an average period of about 30 days elapsed before a relapse occurred. There was considerable variation here, ranging from 14 to 58 days. At this point the atebrin content in the plasma was 3.4 microgrammes per litre.

The results of these experiments confirmed the value of atebrin as a suppressive, and showed that the drug could prevent the occurrence of overt attacks even when infective bites were received over a considerable period of time. The experiment also reproduced the manner and type of infection found to occur in a hyperendemic area. When an uninfected volunteer was bitten on the same day by equal numbers of anophelines harbouring *falciparum* and *vivax* the resulting fever was found to be malignant tertian, just as in the field. Thick smears revealed *P. falciparum,* but *P. vivax* remained latent, being a less rapidly increasing type of parasite. Later, however, after treatment had completely cured the malignant tertian disease, benign tertian still remained latent, breaking out later in the form of relapses. In the infected volunteers who were taking suppressive atebrin the drug completely cured the malignant tertian, and it was demonstrated that if double infection occurred, atebrin administration continued for a month after the last exposure would remove all trace of malignant tertian infection, leaving only relapses of benign tertian to be dealt with in a proportion of the volunteers. Even if this proportion was high, as was the case in New Guinea, the position gained by the use of atebrin as a suppressive was very favourable. The death rate from malignant malaria should be negligible, severe forms such as cerebral attacks should not occur, and blackwater fever should be abolished. These results were somewhat surprising, and surpassed what had been expected. In view of the importance of maintaining an efficient level of atebrin in the body, a study was made of the plasma atebrin levels in thirty-five volunteers taking 0.1 gramme daily over a long period. Considerable individual variation was found, but a curve constructed from mean geometric levels showed that the equilibrium was reached at the end of the fourth week and was well maintained over a period of seventeen weeks. In other work done on this subject a progressive fall was noted after a long period of administration, but these figures were for blood levels. The Cairns figures for plasma levels showed a drop but not of significant degree. Actually the curve rose to an average of about 26 microgrammes during the fifth to sixth week, and then receded to the level of equilibrium, which was 20 to 21 microgrammes. After administration ceased the atebrin concentration fell rapidly, but did not reach zero till about the end of the sixth week. This "die-away" is approximately of the order of a daily decrease of 10 per cent.

A further investigation was undertaken to ascertain the factors which might possibly be responsible for a break-through of malarial suppression. Two series of volunteers were studied. Men in the first series after infection were given daily exercise requiring considerable output of energy, such as walking, swimming and playing games, one group being subjected to unusually heavy exertion such as chopping wood and walking over the hills during the hottest time of the day. In the second series men were

infected more heavily than others and subjected to very heavy exertion throughout the day in humid heat. Some men in this series were also used to investigate the effects of injections of adrenalin and insulin, chill and anoxia. Adrenalin has sometimes been used in other parts of the world to make manifest parasites in the blood, by contraction of the spleen, and its use was also suggested by the possibility of suprarenal stimulation occurring through psychic stress in jungle combat. Doses of 0.5 cubic centimetre of 1 in 1,000 solution of adrenalin given hourly for four doses or two hourly for six doses failed to produce any malarial parasites in the blood. Similarly the possible occurrence of a fall in the level of the blood sugar under combat conditions was imitated by injecting up to 25 units of insulin once or twice a day. Even lowering the level to 70 or even to 40 milligrammes per 100 cubic centimetre failed to produce overt malaria or demonstrable parasites in the blood. Chill was produced by placing volunteers in a refrigeration chamber at — 9°C. for one hour. Though the men wore only boots and trousers and remained at rest during the test period no break-through occurred. The exertion undergone by some of the men in the fatigue tests was extreme; they worked to the point of physical exhaustion without inducing a breakdown of malaria. Some groups even marched over 80 miles in three days over mountainous country, ranging up to 2,500 feet above sea level, where the nights were cold despite the great heat of the day. The men slept out at night without blankets, but in spite of all this malaria was not produced.

Though anoxia is recognised as a cause of relapse in persons with latent malaria, it was not found possible to produce a break-through experimentally. A special group of 18 volunteers was flown to Melbourne and tested in the experimental decompression chamber at the University of Melbourne by No. 1 Flying Personnel Research Unit under the supervision of Group Captain Baldwin, the air force Consultant in Tropical Medicine and Hygiene. After resting five days and moving about normally under quite cold weather conditions they were tested in two sections and spent one and a half to two hours a day for five days at 15,000 feet without supplementary oxygen at 65°F. After a week's rest they were given runs at altitudes of 15,000 to 18,000 feet at 28°F., being allowed to wear overcoats. Volunteers in one group were subjected to a "bends" run at 35,000 feet at 65°F., using supplementary oxygen. In none of these tests did clinical malaria appear, nor were parasites found in the blood after careful search. As the men were taking different doses of suppressive drugs, 0.1 gramme atebrin with and without 1.0 gramme sulphamerazine, and 0.2 gramme atebrin observations were made on their response to anoxia. No difference could be detected which could be attributed to the drugs. After the tests all the men were well and their blood was free from demonstrable parasites.

The suppressive value of lower doses of atebrin (0.3 and 0.4 gramme weekly) was next investigated. Three groups of volunteers who were taking different amounts of atebrin were subjected to infective bites of mosquitoes harbouring *P. falciparum* or *P. vivax*. The usual check observations were

made. Two groups of men were subjected to heavy exertion. Blood estimations showed that a weekly dose of 0.3 gramme atebrin produced an arithmetic mean blood level of 8.8 microgrammes per litre; 0.4 gramme weekly gave a level of 10.3 and 0.7 gramme weekly a level of 24.0 microgrammes. Trophozoites appeared in the blood of 6 out of 7 men taking 0.3 gramme weekly, and in 3 out of 7 taking 0.4 gramme a week. No parasites appeared in the men taking 0.7 gramme a week. Thus atebrin in dosage of 0.3 gramme weekly failed to suppress malaria, and a dosage of 0.4 gramme only partly succeeded.

A further interesting study was carried out on gametocyte production, which incomplete suppression might be expected to favour. In both of the partially suppressed groups of volunteers gametocytes were found in the blood. Vector mosquitoes fed on one of these men were found later to be heavily infected with sporozoites of *falciparum* and were used to infect volunteers in other experiments. It is also interesting that benign tertian parasites were never found even after extensive search of the blood of those who were infected by this type.

After this work on atebrin similar investigations were made into the suppressive power of quinine. Two groups of volunteers were used, one taking 5 grains of quinine sulphate daily in a mixture, the other 10 grains daily. Each group was exposed to mosquito-borne infection by *P. falciparum, P. vivax* and both parasites. An intense degree of infection was induced in these tests as in other experiments, that is, the number of infective bites was higher than might be expected even in hyperendemic areas. In all these tests quinine failed to suppress the strains of parasites used. It was thought possible that either the virulence of the strains used or the intensity of biting might have been too high for quinine to be effective. But there was no doubt whatever that quinine was an ineffective suppressive compared with atebrin. Even 10 grains a day which had been used in heavily malarious areas was insufficient to give protection, though it appeared to delay somewhat the break-through in the experiments.

This work now placed in the hands of the services a method of suppressing both M.T. and B.T., and of curing M.T. by a full suppressive dose, thus eliminating carriers of M.T. and preventing its serious lethal complications. It was now possible to see clearly why quinine had failed to control the heavy infections of Milne Bay and Buna-Gona, and why it was that when malaria broke through suppressive atebrin it was always M.T., and why B.T. came to light later with relapses. The fighting up to the end of 1943 and early 1944 had produced heavy malaria that was plainly due to breakdowns in method and discipline, and the much lessened rate during the latter part of 1944 showed how the same measures could be successful if properly and faithfully applied. The much lower overall malarial rate of 26 per 1,000 per year in November 1944 proved that success was in the grasp of the forces.

Field experiments in the U.S. Army carried out by Colonel M. C. Pincoffs, Chief Medical Consultant U.S. Army S.W.P.A., confirmed the laboratory findings. No volunteers exposed for 40 days in malarious areas

in New Guinea developed malaria while taking 0.6 gramme atebrin weekly, while 64 per cent of a control group acquired clinical infections. After atebrin had been suspended in the first group some 30 per cent of them developed malaria in two to ten weeks after stopping the drug. The effect of atebrin in preventing relapses of B.T. while it was taken was well shown in the 7th Australian Division. Before this division was returned to New Guinea and while the men were in a non-malarious area on the mainland and not taking any suppressive drug the relapse rate was 20.5 per 1,000 per week, 288 men being sent to hospital each week. Maintenance atebrin 0.6 gramme a week was then begun and the division was sent to New Guinea. In three weeks the rate had dropped to 4.5 per 1,000 per week and remained at this level while the troops were stationed in the controlled area of Moresby.

ATEBRIN DOSAGE AND POSSIBLE TOXICITY

Earlier in 1944 attention had been directed to the advisability of using atebrin more intensively, that is, both for suppressive and curative purposes to build up the concentration in the body more quickly than the hitherto used more gradual method. In the Australian forces the question of administering suppressive atebrin in weekly or bi-weekly doses had been considered, but daily dosage was thought to be better as a regular drill, particularly under conditions of jungle fighting. Intensive atebrin treatment had been used, starting with 1.2 grammes in the first 24 hours, 0.8 gramme in the next 24 hours, then giving 0.4 gramme daily for four days, a total of 3.6 grammes in six days. Observations on this and other curative routines will be described later. Where suppressive atebrin was begun in troops previously resting and not exposed to malarial hazard, the procedure favoured was to give 0.4 gramme daily for three days if a speedier "build-up" was desired, or 0.2 gramme daily for seven days, or 0.1 gramme daily for three to six weeks. For motives of security it was desirable to have an alternative. The question of motion sickness arose too, for in combined operations it was important to know if air or sea sickness would be more readily induced in troops who had been taking enough atebrin to give the desired plasma level. The R.A.A.F. carried out swing tests which disposed of this doubt, as atebrin caused no increased tendency to sickness. Tests were also made of dark adaptation in men taking atebrin, and no deterioration could be detected.

A further question was raised in England as to the possibility of greater susceptibility to atebrin after previous period of administration. As toxic manifestations from atebrin taken in standard doses were rare in Australian troops any enhancement of such effects would readily be observed, but no ill effects were noticed when troops returned to New Guinea and resumed regular dosage of atebrin.

During the Huon Peninsula campaign the suppressive dose of atebrin was doubled for some formations, as above related. It was important to know if 1.2 grammes of the drug per week would cause toxic symptoms, and reports from New Guinea Force in June 1944 indicated that such

symptoms were negligible. Evidence from seven battalions and three field ambulances indicated that only a few soldiers complained of discomfort, which at the most consisted of headache, some abdominal uneasiness and occasional nausea. These symptoms were transient, passing off two or three weeks after the increased dosage was begun. Two instances were reported of possible atebrin psychosis in men who had on their own initiative taken excessive quantities of the drug. During 1943 and 1944 a lichenoid eruption of the skin and mucous membranes was reported in numbers which, though not substantial, were increasing. There were reasons for suspecting some connection with atebrin, but pending fuller enquiry care was taken not to allow rumours to arise which might have imperilled the scheme of malaria control. The subject is fully discussed in the section on dermatology and later in this section.

Another and more serious matter was the rumour, entirely false, that atebrin caused impotence. This canard was no novelty. The same had been said at one time of quinine, and in India and Africa atebrin had previously been similarly blamed. The extraordinary pervasiveness and persuasiveness of rumours in communities, particularly when under stress, is well known, and though the suggestion was made that anti-atebrin stories arose from "fifth column" activities there seems little need to invoke a cause apart from that which lies deep in the personality of human beings. Counter-propaganda was issued, pointing out that the hard conditions of warfare in the tropics lessened the responses of men to the usual stimulating effects of normal life. Further, failure to take atebrin produced the dangerous alternative of chronic malaria, with all its debilitating influences on health and vigour.

The whole question of the possible toxicity of atebrin had been most carefully considered by the medical services from the beginning, not merely because of the known peculiarities of this drug in its selective absorption by different tissues of the body, but because of the general principle that toxicity can only be established by prolonged clinical trial. Up to the beginning of 1944, however, it was certain that atebrin in ordinary suppressive doses even when taken over a period of months was practically non-toxic. If occasional instances of idiosyncracy did occur, their number could confidently be regarded as too small to cause a loss of reliance in a drug which could, if properly used, reduce the wastage of armed forces by malaria to a minimum.

D.D.T. AND AERIAL SPRAYING

Early in 1944 keen interest was centred on D.D.T. Experiments were carried out with oily solutions, which were found to be highly toxic to anopheline larvae. Small scale observations showed that one minim deposited from a pipette killed all larvae in one square yard of heavily infected pools. Large bodies of water could not be treated in this way, but in one swamp of half an acre in extent no living larvae could be found after treatment which consisted simply of pouring in a pint of 4 per cent D.D.T. in oily solution 2 ounces at a time at points round the bank. A

spray also controlled larvae, 22 fluid ounces per acre being used. One great advantage of this method was the great reduction in bulk of the fluid used, which was about 1/150 of the oils used hitherto. A cycle of seven days was necessary for effective spraying as D.D.T. would not kill pupae and had a slower and less lethal action on 4th instar larvae. Even with the use of the spray method great economies of men and time resulted, and its value in new areas was obvious. Survey of the Madang-Alexishafen area, for example, showed that some areas were healthy, and others most unhealthy and dangerous. Tactical necessity might demand that unhealthy areas be occupied, and in this event temporary control could be quickly established until such man-made breeding places as wheel ruts, blocked drains and bomb craters could be dealt with mechanically. Actually in the example quoted, Madang, a rate of 1-2 per 1,000 per week was achieved, though this was also due to high atebrin dosage, rigid discipline and the advantages of settling into safe areas under stable conditions.

In May 1944 the project of controlling mosquitoes by spraying an area with D.D.T. solution from aircraft was discussed. In America excellent results were reported from spraying D.D.T. in oil from a Piper Cub, but no particulars had been received in Australia of trials in which fast operational types of aircraft were used. Data concerning weather, the behaviour of aerial sprays and their droplet pattern on the ground were likewise not to hand. A joint committee of the Australian Army and Air Force undertook an investigation of the behaviour of oil sprays in the air under varying conditions of wind and elevation of the aircraft. No. 1 Aircraft Performance Unit carried out modifications of an aircraft, arranging that the outer wing tanks could be used to distribute the oil through jettison valves, and supplied crews for the experimental work. The only suitable machine readily available was the Beaufort Bomber, which fortunately proved most satisfactory, as it provided good visibility to the pilot, was easily manoeuvred, and had good carrying capacity. At first attention was paid rather to the production of large droplets on the ground, but later experiments accorded with the findings then coming to hand from overseas that small droplets were more lethal to mosquitoes. The oversea work, however, related only to laboratory experiments, the results of which were not applied in Britain or America to actual spraying from aircraft. In New Guinea the Australian Services used these results in practice and found it advantageous to regulate flying times so as to utilise downward movements of air to deposit spray where it was most needed. Under optimum conditions a dosage of 2 to 2½ quarts per acre of 5 per cent D.D.T. in oil was found to give better than minimum effective distribution. The malariologists of II Corps reported very satisfactory results from 300 gallons of spray per square mile although the penetration of spray through foliage could not be checked accurately. The ideal method was for the aircraft to fly 100 feet above tree level in straight line runs 100 yards apart, and though cross-wind runs were preferred the flight pattern dictated by the topography could be followed with good results. Accurate flying was called for, especially when steep turns were necessary to avoid

obstacles. The results were very satisfactory. Larvae were killed and did not reappear for a week. After an initial substantial drop the adult mosquito population tended to rise again, owing mainly to reinforcements from outside areas, especially if the area sprayed was small. A light wind was found preferable to calm, but more than half the early mornings in New Guinea were found suitable during this investigation. There was still a world shortage of D.D.T., but manufacture in Australia was being expedited. Obviously control of the air was necessary to make the use of this now new weapon practicable, but its tactical value in stabilising the hygiene of new areas was evident. Australian experience was found helpful in Britain in calculating the supplies needed for military formations.

Before the planned combined operations were carried out early in 1945 the routines for air spraying of D.D.T. had been well worked out. In general it was not carried out where the planes would risk exposure to hostile anti-aircraft fire, or where the enemy might suspect a gas attack. The indications were the presence of presumably infected anophelines in a newly occupied area, an outbreak of dengue fever, difficulty in applying other control methods to inaccessible areas, and an outbreak of dysentery in an area infested with flies. Areas for spraying were selected rather for their proximity to concentrations of native population or to areas recently occupied by the Japanese than for the presence of suspected breeding grounds. A zone of 200 to 300 yards around these camps was included in the spraying. No particular advantage was found in adding pyrethrum to the spray solution. Dosage of 1.8 to 2 quarts of 5 per cent solution per acre was recommended; spraying for adult insects was done only at dawn to ensure the correct drift of tiny droplets, in the region of 5-15 microns diameter, but anti-larval spraying, for which larger droplets were effective, could be done at any time during the day. The lines for the run were clearly indicated to the members of the R.A.A.F. carrying out the spraying, preferably by smoke markers laid by a malaria control unit. In most particulars the details were worked out in the preliminary experiments. The results were very satisfactory on the whole. A 95 per cent kill or better of adult mosquitoes resting out of doors was usual; practically all larvae died within twenty-four hours except occasional late 4th stage larvae. Pupae were not killed though the adults sometimes did not survive emergence. Eggs were not killed. Larval destruction was not so satisfactory with *Aedes scutellaris* or *albopictus,* vectors of dengue. Mosquitoes in dwellings were much less affected, this was particularly so with *Aedes aegypti.* Flies were killed off almost entirely, but the larvae and pupae were unaffected. Heavy vegetation reduced insect destruction to some degree, but the penetration of fine droplets was remarkable. The frequency of spraying depended on the genus and species of insect.

In the early stages of an operation it was not considered wise to rely on D.D.T. spraying alone, since planes could not always operate so soon, accurate marking was difficult, and adult mosquitoes resting indoors were little affected. Pyrethrum spraying by hand or by Freon bombs was carried out as widely as possible on the day of the landing, particularly in native

quarters. Power sprays or knapsack sprayers were used to produce an atomised mist in affected areas out of doors, and D.D.T. solution was sprayed on the walls of shelters in order to kill resting mosquitoes by its delayed action. This last manoeuvre was of value in reducing sporozoite and transmission rates, quite apart from reduction of mosquito populations, since the resting mosquitoes were already engorged with blood. The same technique was found useful in the treatment of vegetation with heavy dosage of D.D.T. in oil, spraying two or three gallons of 5 per cent solution per acre. In New Guinea the reduction thus produced in mosquito populations lasted for about one week, much less than the three weeks' period reported from Burma. In any case some reduction in sporozoite rates resulted, though the method used a considerable amount of D.D.T.

The order of priority for spraying after landing was as follows: treatment of the beach maintenance area and a fifty yard zone around, and thereafter native compounds, main dressing stations of field ambulances, rest camps, casualty clearing stations and transit areas for troops.

MALARIA IN NEW GUINEA IN 1944-1945

In November 1944 fresh operations were begun. The action areas were now widely spread. Troops were maintained at base areas in New Guinea in reduced numbers, the chief areas now being on the north coast, at Lae and Madang. Here conditions were now well stabilised. At Morotai, north of the Halmahera island group a forward base was established from which combined operations were planned in Borneo, and carried out after April 1945. A divisional group pressed on along the north-eastern coast of New Guinea to capture and hold the Aitape-Wewak area. In New Britain, following up previous Allied actions, a division established a base sub-area and in the Solomons a larger force operated and stabilised the position. In each of the operational groups there were numbers of new units without previous experience of malarious terrain, and the troops in all these islands north of the Australian mainland totalled about 188,000. There was a high malarial risk in all these areas, though some of them were well controlled.

Previous experience had shown that New Guinea and New Britain were as a whole hyperendemic, though there was considerable difference in various areas. Not even in the controlled base areas could precautions be relaxed. In the Solomons the malarial hazard was equal to that in New Guinea, for the ascertained native spleen rates were high. The experience of nearly 800 Japanese prisoners concentrated in Fauro Island had paralleled the earlier experiences of the Australians escaping from Rabaul, in New Britain. These men coming from non-malarious Nauru Island, with their own medical service, came in contact with other heavily infected troops, with the result that an epidemic swept swiftly through them and killed over 200 men. Borneo was known to be malarious along the coast except for the controlled commercial areas. Even these, under Japanese control, were likely to be still hyperendemic. These multiple proving grounds were a challenge to the anti-malarial organisation. At the begin-

ning of these active operations the overall malarial rate for areas outside Australia was 0.5 per 1,000 per week, or 26 per 1,000 per year. In January the annual rate per 1,000 rose to 75, but fell again to 39 in March. It was essential that the wastage of men through malaria should be kept as low as possible, for at 31st January 1945 a review of the records showed that since June 1943, 67,172 men had had malaria, suffering 132,014 attacks of the disease, and spending in all 2,545,585 days in hospital. At this point there was a serious interruption in the steady low rate owing to an outbreak in the 6th Australian Division in the Aitape-Wewak sector. This force had aimed at producing a record low rate in these operations, and the breakdown, which was responsible for 300 to 400 cases of malaria a week in May and June 1945, was a great disappointment to all concerned. This epidemic is of such interest and importance in the whole story of malaria that it will be discussed at some length.

Excluding the 6th Division at Aitape-Wewak and base troops, about 130,000 troops were exposed to malarial infection for periods of from six to twelve months, and out of this force only 1,256 attacks of malaria were reported over a period of nearly one year. In the Solomons the rate was 22 per 1,000, and in New Britain 18 per 1,000, while in the forces at Morotai and Borneo the incidence was only 3.7 per 1,000. In the Solomons heavy fighting went on under difficult conditions, and yet the usual average weekly rate was consistently low with few exceptions. In a few instances localised outbreaks occurred. For example, some 60 cases were reported in a fortnight at Bougainville from units of one brigade which were found to be lax in supervision. The overall rate for these campaigns was seldom above one per thousand per week.

In the Borneo operations forecasts were difficult to make beforehand, as local conditions were not clearly known and the degree of enemy resistance could not be surely estimated. By this time, 1945, organisation was good, supplies were adequate, and sea and air control had been gained, but even so the malarial rate was gratifyingly low. Out of a body of troops never less than 70,000 during a period of five months, 17,000 admissions were made to medical units and of these only 218 of the patients had malaria, less than 1.3 per cent. Only 97 of these 218 attacks were primary, and mainly due to malignant tertian, the rest being due to subsequent attacks. One death occurred at Labuan from cerebral malaria. Incidentally it was interesting that the admissions for skin disease were ten times the number for malaria.

Even admitting that some of these operations were carried out against less sustained resistance, remembering the high incidence of malaria in previous years in some relatively safe base areas, these results were highly gratifying. The introduction of D.D.T. spraying from the air must have had a salutary effect on the incidence of all insect-borne disease, and the whole of the Borneo operations in particular were a tribute to preventive medicine. It must be pointed out too that the incidence of relapses of B.T. fever among the troops exposed to risk in this campaign was also low. After the 7th and 9th Divisions returned from their campaigns in 1943-1944 it

will be remembered that their relapse rate was very high after they ceased to take atebrin, reaching a peak of 37 per 1,000. It will be recalled too that experience both in the field and the laboratory showed that it was M.T. that broke through to cause overt malaria in combat areas and B.T. that appeared later. These relapses after the men returned to non-malarious areas were an inexorable witness to the fact of infection, even though that infection had been latent under the controlling influence of atebrin. But in the 1944-1945 campaigns the relapse rate in the Atherton areas after all the troops returned south even at its peak in the end of 1945 never reached 15 per 1,000 per week. Moreover, not all these relapses were due to infection during the recent campaigns. Of course these latter figures do not represent the total number of men who had relapses of malaria acquired in these campaigns, but they are reasonably comparable with the figures for the preceding year.

Brigadier Fairley in an analysis of the experiences of one brigade (6th Australian Infantry Brigade) has pointed out how high an ultimate benign tertian rate may be expected after exposure. This brigade was twelve months in Buna and Lae areas in New Guinea, and nine months in New Britain. Early exposure in Buna produced a very high malarial rate, but improvements in control lowered this, until in August 1944 the average weekly rate was below one per thousand, and had not risen higher than 5 per thousand. After its service in New Britain the formation was disbanded piecemeal, and exact figures are not obtainable, but the percentage of men suffering relapses in three battalions was about 45. The rate rose to 125 per 1,000 in one week. Even taking the figures for two months after the cessation of suppressive atebrin, a period too brief to include all relapsing attacks, Fairley estimated that the ultimate infection rate for benign tertian would be at least 70 per cent. Previous experience in New Britain suggested that transmission of M.T. was considerably greater than B.T. in the regions where Australian troops were exposed. If this be so the value of atebrin as a suppressive agent is evident, and its capacity to cure M.T. is demonstrated. When the war ended the Australian troops were on the whole in good health, and their rehabilitation from the point of view of physical condition in general and of malaria in particular was not difficult.

THE AITAPE-WEWAK EPIDEMIC

The methods evolved for controlling malaria in the field were vindicated by the excellent results obtained in the last year of war. Yet there is a chastening experience still to be described, that of the epidemic in Aitape-Wewak among the 6th Division, and to a lesser extent the 3rd Australian Base Sub-Area, which caused 6,906 casualties. Operations began in the Aitape area in November 1944. The force had to fight back along 100 miles of coast and also in the mountainous inland sectors. Wewak was occupied in May. The malarial hazard was high over the whole area, particularly so on the coast. In some of the mountainous parts transmission was relatively low, but there was no doubt that the area as a whole was hyperendemic throughout the year. The coastal area was narrow

and flat, and intersected by a number of rivers and innumerable creeks, which fed swamps and towards the foothills ran through dense rain forest. There were concentrations of natives in different parts of the area as the campaign progressed with variable degrees of contact with the troops. Considerable infection existed in the native groups, especially among the infants, as will be shown later. There was also a pool of infection among the Japanese. Mosquito breeding was found to be heavy, the most abundant vector was *A. punctulatus moluccensis*. Many breeding grounds existed particularly near the coast, and there were innumerable bomb craters filled with water. Malaria control units worked with good effect, and eventually reduced the mosquito population to 5 per cent of its initial total in areas where such work was possible. Owing to the nature of the campaign there was a constant lag in the application of control to active areas. The spraying of D.D.T. from the air was used more extensively than in any campaign hitherto, but it was never possible to spray areas before or even soon after their occupation. Shortage of supplies also restricted the use of the method towards the end of the period. It was recognised from the beginning that control must rest on a firm basis of personal protection and the taking of atebrin.

In December an undue malarial rate was noted in certain units of one brigade, the 19th. The whole 6th Division was already working under very strict hygiene orders, but the commander made prompt enquiries and, finding evidence of slackness in anti-malarial discipline, took firm disciplinary measures. As a precaution the whole brigade group concerned was placed on a double dose of atebrin, 0.2 gramme daily for three weeks.

At the end of January the Commander-in-Chief, General Blamey, held a conference at divisional headquarters at which the position was discussed, and even more strict drill at atebrin parades was adopted and the rigid enforcement of all control measures emphasised. Three teams of medical and combatant officers were appointed to make searching survey of all relevant matters. Thorough investigations were made on the spot by representatives of army medical headquarters and it was concluded that conditions of infection were not more severe than elsewhere, that atebrin was not at fault in composition or action, and that the outbreak was due to faulty atebrin suppression. It was admitted that the divisional orders relating to the administration of atebrin were strict to the point of actual harshness. The method of atebrin administration included the actual placing of the tablet in each man's mouth, and the inspection of his empty mouth after swallowing. Nevertheless there was evidence that there were slips in the use of repellent lotions and loopholes in attendance at atebrin parades, and even in the generally excellent dress discipline (one very high officer was observed not to be wearing gaiters).

The 19th Brigade went back to rest at the end of January, and by this time malaria had increased rapidly, the rate reaching 44.8 per 1,000 per week. Accordingly the suppressive dose was raised to 0.2 gramme daily for the whole division. The brigade in question reverted to 0.1 gramme after a month, but the other two brigades, 16th and 17th, con-

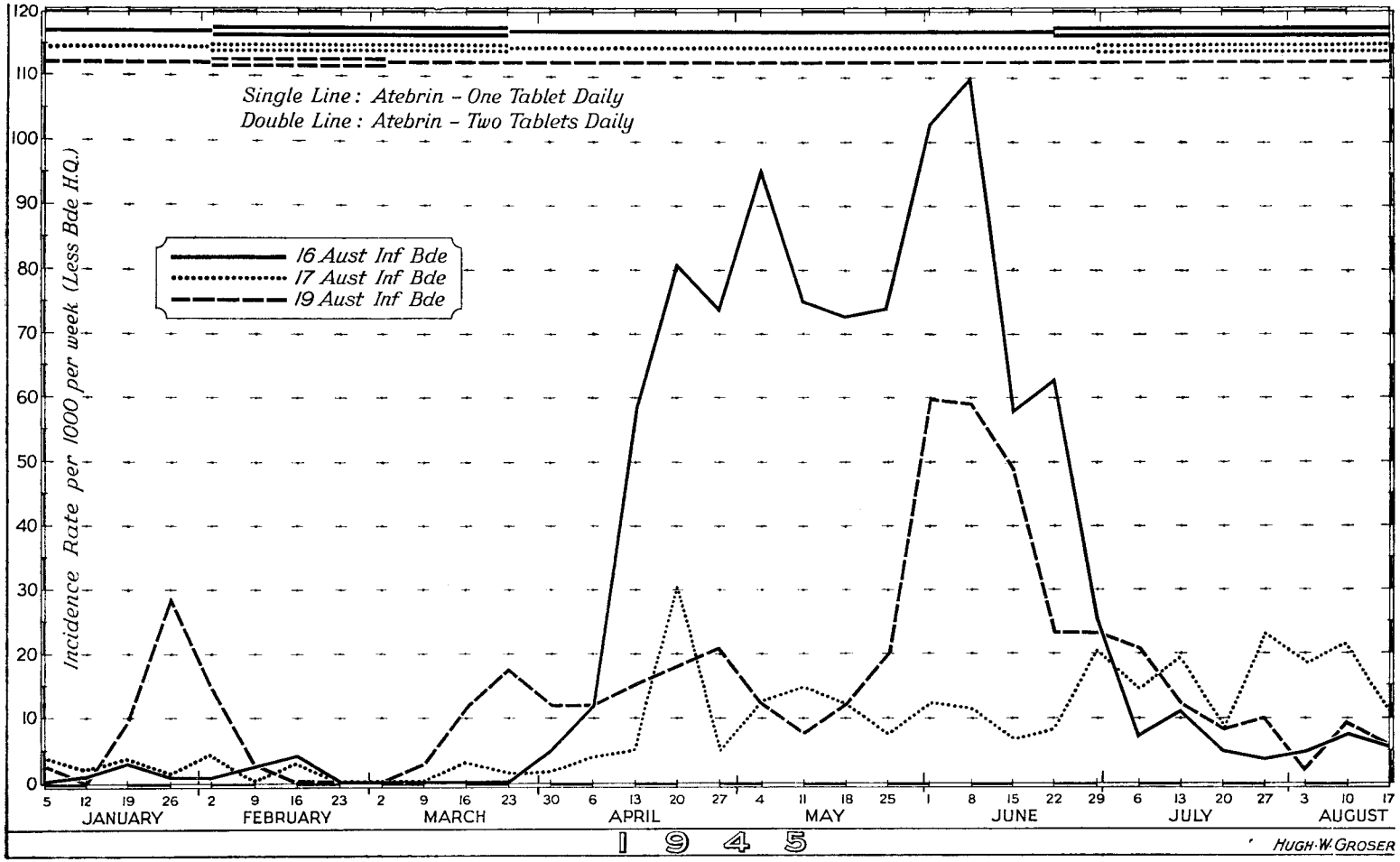
tinued the higher dosage for another month, during which the 17th moved into the Torricelli Mountains, and remained chiefly in the higher ground for the remainder of the campaign. Here transmission was apparently at a lower level, probably accounting for the lower incidence of overt malaria experienced by this formation. At the end of March the whole force was back on the usual suppressive dose of 0.7 gramme a week. The sharp outbreak just described subsided by the end of February. It attracted great interest and caused not a little anxiety. No parallel existed on other fronts. In the Solomons, with the exception of a brief rise to a rate of 47 per 1,000 due to a localised breakdown in control, the incidence was uniformly low, so too in New Britain. In both these areas high rates of transmission and incidence were known to exist, yet the rates were better than those previously obtained in some relatively settled areas.

The divisional commander, General J. E. S. Stevens, and his responsible officers were very keen to be able to show a record low malarial rate, for, though many of the troops were reinforcements who had not had previous experience in the tropics, the background and tradition of this, the first division of the A.I.F. to be formed and to enter action, were powerful influences.

By March the situation was thought to be under control, but in April a large-scale outbreak began. The graph illustrating the steep rise and high level attained is characteristically that of a malarial epidemic. The three brigades were not equally attacked. The 17th Brigade, chiefly in hilly country, reached a maximum of 30 per 1,000 per week in July, the 19th reached 65 per 1,000 per week in the beginning of June, and the 16th reached the peak of 113 per 1,000 per week in the first week of May. The initial rise began in each brigade at approximately the same time. Double suppressive dosage of atebrin was ordered for the 16th in June when some fall in rate had begun, and the epidemic terminated in July. Increased dosage was ordered for the 17th Brigade, but its rate, never very high by comparison, did not subside for some weeks. The 19th Brigade continued taking the usual dose and after a sharp rise the rate fell at the same time as that of the 16th.

THE EPIDEMIC ANALYSED

It will be seen that there were some inconsistencies hard to explain. Out of a force of 17,500 men, 4,838 individual soldiers were recorded as having one or more attacks of malaria. Some 78.2 per cent of the total cases were due to M.T. or Mixed M.T. and B.T. infection, and 10.7 per cent to B.T., 11.1 per cent were not confirmed by the finding of parasites. The attacks were on the whole very mild in nature, though four deaths occurred. During the period when the epidemic took place and until the end of the war in August 1945 the malarial rates in other operational areas remained consistently low. Here was a problem posed for solution. Was it simply due to breakdown in malarial discipline and control, or were there other factors? An extraordinary amount of argument



Epidemic of malaria in Aitape-Wewak

took place and intensive enquiries were made within the affected formation, by higher formations and by the medical directorates at army headquarters, and finally by research teams under Brigadier Fairley. Commanders of a combatant and a medical unit were sent to tour other operational areas, but they found no evidence of anything done there which was left undone in the Aitape-Wewak sector. Fairley has made a detailed statistical survey of this epidemic and has also described the findings of work done on the problem by the Medical Research Unit at Cairns and by a field section of this unit which was specially set up to make local investigations. The information available falls into three categories, a statistical survey, an account of the special scientific investigations made in New Guinea and at Cairns, and a consideration of other circumstances and relevant material bearing on the question. Some of the factors mentioned are beyond dispute, others are more imponderable and speculative.

The nature of the epidemic was of itself not unusual, the steep rise suggests the combination of factors such as a degree of non-immunity of those affected, a high concentration of vectors, and heavy breeding, a high transmission rate, and the provision of a pool of gametocyte carriers. The last may be left for the present; the other factors are understandable provided control measures were inadequate, or if a race of parasite was present less amenable to suppression than any hitherto encountered in the islands. The majority of infections were by *P. falciparum,* as might be expected in such an epidemic. It would follow then on the basis of previous experience that latent infections by *P. vivax* would be manifested later. But if for reasons of faulty control, principally deficient atebrin dosage, it would be expected that M.T. would break through and not B.T., since the latter requires substantially less atebrin for its suppression. Both experimental and field work have shown this. If primary B.T. infections occur it will be surely due to a defective atebrin level in the blood below that given by taking 0.1 gramme atebrin a day.

Such an outbreak of B.T. did occur here, and whether it was primary or not, a rate of 4.6 per 1,000 per week is hard to explain except by assuming too low an atebrin level. The rates of M.T., B.T., and mixed M.T. and B.T. fluctuated after the same pattern during the outbreak. It should be remarked that the total consolidated percentages recorded of the types encountered (78.2 per cent M.T. and 10.7 B.T.) are much lower than those found at a mobile bacteriological laboratory, where 98 per cent of 298 cases were M.T. This high percentage was unique in army experience in New Guinea, and suggests that the B.T. was being suppressed while M.T. broke through. What exact significance can be attached to the total B.T. figures for the whole period is thus doubtful.

Consideration of multiple attacks is also interesting. Fairley points out that in troops of the 6th Division the average of attacks per patient was 1.3 and in the base sub-area 1.15 over a period of eleven months. Medical officers in hospitals reported an unusual tendency for recrudescent attacks of M.T. to occur; some of these could not have been fresh attacks as they occurred within a few days of completing a course of treatment. The

2/11th Australian General Hospital reported 390 attacks in 250 men, and the Medical Research Unit 160 in 97 men, and a battalion survey gave 45 in 34 men, a total of 595 attacks in 381 men. It will be seen that this ratio of 1.6 to 1 is higher than that above quoted, which is derived from base records.

The question of the cause of these recrudescences or relapses arises at once: it has been touched on earlier in this account. There seems no doubt that this was a genuine experience, but how much of it was due to deficient taking of atebrin in hospital may be questioned. In two hospitals the institution of stricter methods, such as the inspection of the patients' mouths, reduced the number of recurrent cases in some instances. Reliable observers on this and other occasions have stated that under strict conditions recrudescences did occur after or even during follow-up maintenance courses. Parasitaemia of a transient order has also been observed. A clinical impression held by some medical officers was that these phenomena were more frequent at Aitape-Wewak. No controlled figures can be given; some observers considered that controlled atebrin intake definitely lessened the number of recrudescences, but this cannot be proved.

While speaking of hospitals, some figures may be mentioned obtained in a survey of 500 patients. More patients were drawn from amongst those who had served 40 to 49 months than any other period, and 7 months in the area. It was also observed in Lae base sub-area that though 31 per cent of the patients with malaria came from Aitape-Wewak, 96 per cent of those developing relapse after five days in hospital came from this area. Pursuing more closely the question of relapses, we find that the percentage of individuals contracting subsequent attacks was much the same as that found in the divisions which campaigned in the Huon peninsula. The percentages for the 7th and 9th Divisions were 28.3 and 21.3 respectively, that for the 6th Division in this campaign being 22.7. This will be discussed further presently in connection with the possibility, already mentioned, of a parasite relatively resistant to atebrin.

Another important statistical fact emerged in the incidence of malaria in officers and other ranks: only 15 per cent of the officers with the 6th Division were admitted to hospital with diagnosed attacks of malaria. This is only half the incidence in non-commissioned officers and men. This may be due in part to greater opportunities for avoiding malarial infections, but is certainly in many instances due to higher atebrin dosage. Numbers of officers took more atebrin on occasion, especially if they suspected the nature of any indisposition. Moreover, it was more important for them to keep on their feet owing to the strictness of the disciplinary measures. C. H. Selby, a commander of a field ambulance, has pointed out it might perhaps be thought an indication of bad discipline that many officers took more than the standard dose because of the threat of court martial and disgrace should they contract malaria.

It will be evident now how important it is in the understanding of this epidemic to know just how much atebrin was taken by officers and men of this division. Was there a widespread laxity in taking atebrin on the one

hand, or was the standard dose insufficient for some unknown reason, or was the better result obtained by some formations due in part to higher, if unofficial, atebrin dosage? Officers could more easily have access to atebrin than other ranks. Lieut-Colonels Jaboor and Selby, in visiting other fronts officially, found that in Bougainville and New Britain more than one tablet a day was frequently taken. Instances occurred of units taking additional atebrin when carrying out special work to avoid being disciplined for contracting malaria or to retain a previously good reputation. Commanders finding their rates rising would take similar action to keep the rates down. It has been suggested that one reason for better results in Bougainville and New Britain may have been a higher or at least a more consistent atebrin level in the blood obtained by these means.

In view of these considerations it is of great interest to see what happened when a unit was introduced into the Ataipe-Wewak area which had earned a reputation for excellent anti-malarial discipline in other hyperendemic areas. The 8th Infantry Brigade was moved from the Madang-Alexishafen-Hansa Bay sector to Wewak during July. This brigade had carried out long advances along the coast, and after some early breakdown in two units had maintained a low rate. Two battalions took over fixed positions at a late stage of the campaign, and within several weeks of this they both showed a definite increase in the incidence of malaria. This was particularly so in one battalion, whose rate rose to 38 per 1,000 per week in August. Following the administration of double dosage of atebrin a prompt fall occurred to a low level. This example pointed to the probable existence of some other factor. Thus the doubts that had arisen that 0.7 gramme of atebrin might not always suppress malaria in this sector called for fuller investigation. Several senior officers had contracted malaria, including a brigade commander and the commanding officers of two field ambulances. Numbers of instances occurred in which the most reliable N.C.O.'s and men in units had overt infections. Such happenings had been observed before, reported by responsible and reliable persons, and here an impression was widely held in the field medical units that more malaria was occurring than they believed could be accounted for by failure to take atebrin. The mild nature of the cases has been commented on already: it was suggested that this was due to the partial protection of atebrin. On more purely hypothetical foundation was the idea that some degree of premunity existed in many individuals and that this might explain how out of an epidemic of mild nature numbers of cerebral infections would appear, as they did, with occasional deaths. This suggestion assumed that an infection which otherwise might have been more dramatic and severe, had not lost its peculiar property of causing such local manifestations as cerebral malaria.

Some doubts were also expressed as to the efficient absorption of atebrin. Was there some other factor such as hookworm hindering absorption? An increased incidence of hookworm was noted in hospitals in the field, but it was not certain that similar findings might not have been made before if more intensive search was undertaken. Besides, in Bougain-

ville, hookworm of unusual intensity of infection had been found, but without any special obvious reflex on malarial incidence. The question of intercurrent alimentary disease in relation to the absorption of atebrin had also been raised. Interesting observations were made by 1st Lieutenant J. Maier, 1st Lieutenant F. B. Bang and 2nd Lieutenant N. G. Hairstrom of the American Malaria Research Unit (3rd Medical Laboratory). With clinical assistance from the 2/7th Australian General Hospital they determined the plasma atebrin levels in patients with infective hepatitis, and diarrhoea. No difference could be found in the plasma atebrin content of these men and of controls in either instance. Thus there was no evidence that these infections would hinder absorption of atebrin.

The same team also investigated plasma levels of men in the field. Among men claiming to take atebrin regularly they found considerable individual variation in the plasma atebrin concentrations. This was thought to be due to failure to take the prescribed suppressive dose in the great majority, though it was recognised that daily variations in the analytical method, or in individual response to the drug, or a variable ratio of free to bound atebrin in the blood might also cause some fluctuation in the estimations. The plasma concentration of atebrin bore only a rough relation to the free and presumably active drug in the plasma. It appeared also that the malarial rate did not vary in proportion to the expected efficiency of atebrin suppression in an infected group, though there was no question that a high malarial rate could be possible only if atebrin suppression was poor.

INVESTIGATIONS AT CAIRNS

The research units set about elucidating the following problems. Was atebrin correct in composition and tablet dosage? Was it adequately absorbed? What were the average atebrin plasma levels in men on reputedly standard dosage? Did malarial strains isolated from soldiers in this area behave in a manner different to strains encountered hitherto in the islands? Forty selected patients with overt malaria were flown to Cairns and hundreds of specimens of blood plasma also for atebrin estimations. These specimens were taken without warning from soldiers on atebrin parades, those selected having varying degrees of pigmentation so as to secure a representative cross section. Lieut-Colonel Mackerras in addition carried out special investigations dealing with epidemiology with reference to control. Definite answers were obtained to these questions.

The atebrin tablets contained never less than 0.101 gramme of atebrin hydrochloride. The distintegration times were within effective limits, though one type of tablet took from five to fifteen minutes to distintegrate in water. An occasional tablet could be held in the mouth for a time without dissolving. Evidence was obtained that a few men of unsatisfactory or unstable temperament practised some means of evasion, perhaps with the help of chewing gum. Specimens of plasma collected by the field research section were analysed for atebrin by a standard method. Very close agreement was obtained between the plasma levels of these men

who stated that they were taking 0.7 gramme atebrin a week, and those found in volunteers at Cairns who were known to be taking the same dosage. The geometric mean of the level in microgrammes a litre was 21.56 for Aitape-Wewak and 20.12 for Cairns, standard deviations being 1.37 and 1.59. The patients with overt malaria were found to have higher levels, 27.57 mean, due probably to their taking extra atebrin when they felt unwell. Agreement was not found between the plasma levels of men alleged to be taking 1.2 grammes a week at Wewak and volunteers known to be taking this amount at Cairns. The mean level for volunteers was 43.1 microgrammes, that for the Wewak men was 31.7.

It will be realised that the same certainty cannot be felt concerning the actual dose taken by the New Guinea men as that taken by the volunteers. Despite the correspondence of the 0.7 gramme a week levels there is no proof that these men were not taking an occasional extra tablet. It seems likely that the lower levels with the 1.2 grammes weekly dosage was due to irregular intake. In general this evidence points to a sufficient dosage of atebrin in the division to ensure protection against the strains previously investigated at the research unit.

Study of spleen rates and parasite rates indicated a high general rate of infection estimated at 90 per cent at the time of review. After Milne Bay and Buna-Gona campaigns high parasite rates were recorded in men who were apparently well, as has been previously told. Rates of 16.0 per cent and 12.0 per cent for blood parasites and gametocytes respectively were found in these men, and though these unprecedented rates were not approached in the Aitape-Wewak area, the rates there were 5.0 to 5.5 per cent and 2.0 to 2.5 per cent, while the figures for Bougainville were 1 per cent and 1 per cent and for Morotai-Borneo only 0.17 and 0.05. Some men at Wewak were doing their usual work while carrying large numbers of parasites in their blood, and did not contract overt malaria. *Plasmodium falciparum* was found in the blood of men who were well and whose plasma contained a theoretically adequate concentration of atebrin. This occurred only in the Aitape-Wewak area, and had not been seen before by the staff of the research unit. This pointed again to the possibility of an atebrin-resistant strain. Soldiers thought to be the most likely subjects of infection by such a strain were flown to Cairns, particularly those with attacks of M.T. repeated within a short time during the administration of a maintenance course of atebrin, those with cerebral malaria and those with hyperinfection. Seven out of nine strains isolated from these soldiers were found to be unusual in their resistance to atebrin. Volunteers infected from mosquitoes carrying sporozoites from these strains contracted malignant tertian malaria which was either not suppressed by 0.1 gramme atebrin daily or if suppressed not cured by this dose. In some instances the disease was suppressed but not cured by 0.2 gramme of atebrin daily. In several volunteers recrudescences of M.T. occurred after a standard course of treatment while maintenance doses of atebrin were being taken. Larger doses of atebrin and higher blood concentrations were more effective in dealing with this type of parasite.

Other drugs then under trial at Cairns were tried. No alteration in sensitivity was found with quinine, "Resochin", sulphadiazine or "Paludrine", but in two volunteers "Santochin" as well as atebrin suppressed but did not cure the infection.

Whether this atebrin-resistant quality could be lowered by successive passage through mosquitoes and men could not be ascertained: one instance suggested the possibility. No similar results could be obtained with the strains of *Plasmodium vivax* isolated from the Aitape-Wewak area. All these strains behaved like the others previously tested at Cairns. Thus definite proof was obtained of an atebrin-sensitive strain of *P. falciparum,* but no proof of any such strain of *P. vivax.*

It was of particular interest to determine how prevalent this strain was in the Aitape-Wewak area, and whence it was derived. Fairley has pointed out that the incidence factor of secondary attacks in the 6th Division was 1.3, and that therefore failure to obtain radical cure of M.T. in the area must have been rare, the prevalent strain producing overt attacks being atebrin-sensitive. From considerations of the number of recrudescences and relapses experienced he argued that the chance of acquiring a recrudescent form of malaria in Aitape-Wewak was not greater than in the Ramu or Markham Valley, all the figures being similar, hence that the percentage of men affected with the resistant strain would not be higher than about 20 per cent. There is, however, a possibility that an undetermined proportion of men who had had one attack of M.T. took more atebrin thereafter, thus reducing their liability to recurrence. Although the recrudescence rate may be higher than 1.3 as pointed out above, this figure may be a near approximation. Even this cannot be stated with certainty, however, as exact evidence about atebrin intake and plasma levels in the division does not cover all classes of officers and men, for instance those who had had an overt attack of malaria.

FURTHER ENTOMOLOGICAL RESEARCH AT WEWAK

How did this strain arise? It was suggested that insufficient atebrin intake may have caused this characteristic of resistance to appear in a proportion of *falciparum* parasites. A similar phenomenon is familiar with drugs like sulphonamides and penicillin. If this were so, from what gametocyte pool did the epidemic arise? Interesting epidemiological evidence was accumulated by Mackerras and Aberdeen in the Aitape-Wewak area. They made a study of the naturally occurring and uncontrolled infection in the native community. The spleen rates and parasite rates were estimated in adult men and women, children and infants drawn from a population of over 1,000 in the neighbourhood of Wewak. These were compared with similar observations made on Japanese prisoners in Wewak and on Australian soldiers in the area. The highest spleen rates were in infants and children, of course, up to 93 per cent; the parasite rates were much higher also, but a point of interest is that they were very

much higher in infants than in children. The following figures taken from Mackerras and Aberdeen's table are of interest:

	Hwain natives				
	Infants	Children	Adults (men)	Japanese	Australians
Parasite rate .	92%	59%	29%	47%	5%
Infection rate .	130%	71%	32%	57%	5%
Gametocyte rate	49%	16%	6%	22%	2½%

Mosquito dissections showed a 2 per cent sporozoite rate in the Hwain villages, but 0 per cent in the troop encampments in Wewak in July. Particular attention was paid to the possible sources of infection in the military community. These sources were, in terms of this survey, for *P. falciparum* infants, Japanese and the Australian troops, in that order of importance, and for *P. vivax,* Japanese and children. Contact of troops with infants and children was slight, but with Japanese was close, especially in forward units where clinical malaria was prevalent. This survey is of course a localised one: parasitological and immunological differences were found in surveys of different areas, such as Lae. Mackerras and Aberdeen concluded that the troops acquired most of their infections in the coastal zone from the Japanese and probably also in the hills, where the Japanese were numerically preponderant. It was further pointed out that in the hours before dawn an off-shore drift of air would bring the mosquitoes in from the infected areas. Malaria pickets patrolling camp areas at night spraying tents were instructed to look specially for "large bare surfaces" of skin in contact with nets.

These points have been raised here as they have some bearing upon the origin of an atebrin-resistant parasite. The hypothesis has been put forward that this strain arose through being circulated among troops who were taking inadequate amounts of atebrin. It is hard to reconcile such a suggestion with the findings of this local epidemiological survey. If such a strain originated among the Japanese its transfer to Australian troops was easily possible, particularly in this campaign, both in the coastal sector and the hills. In the mountainous areas it was not uncommon for opposing forces to be on ridges separated by difficult barriers of ravine and jungle though actually close by direct distance.

CONCLUSIONS ON AITAPE-WEWAK

It is evident that there were breaks in malarial control and discipline, but it is certain that the same applied to all other areas at one time or another, despite a generally high standard. The question of morale has been raised: it is difficult to assess. Some officers thought that fatigue due to difficult fighting was a factor, combined with the feeling that the campaign, though strenuous, was not of major importance. There is no evidence that such a feeling was more prevalent there than elsewhere. The rules of atebrin administration were very strict: it is hard to see how there could

have been more loopholes than in other formations, though some undoubtedly occurred. If anything, the measures adopted were too harsh, and these may have reacted unfavourably on the men.

It is interesting that Lieut-Colonel English, malariologist to First Army, reported that of 1,500 men from many areas, but not including 6th Division, some 15 per cent still believed that atebrin would cause impotence or sterility. Quite apart from this, senior medical officers of the 6th Division considered that the emotional and intellectual attitude towards suppression of malaria was a factor of importance. In this connection it will be remarked that, although the possible causes of break-through of malaria in men taking an adequate dose of atebrin were very thoroughly investigated at Cairns, the laboratory results are not necessarily applicable to field conditions. In some convalescent depots on the mainland men have been known to court relapses by prolonged cold showers. Medical officers have in some cases believed that relapses more frequently followed such action, but this is only an opinion unbacked by controlled evidence. It must be admitted that the psychological component of fatigue, or the effect of distress, anxiety or other more or less turbulent emotion of stress cannot be reproduced experimentally. Such possible factors can only be regarded as imponderable, but no physician will question their importance.

Summing up, this epidemic had the usual features of a swiftly increasing outbreak of malaria in a closed community. It occurred in troops of excellent fighting qualities operating under strenuous and difficult conditions in a highly endemic area where transmission of malaria was well established before their arrival. Ground control was good, but owing to military conditions was always catching up, except in settled areas. Personal protection was not always first-rate, in which it probably did not differ from other areas. The slightest laxity would cause infection, in point of fact some 90 per cent of the troops in the area were infected. It must be remembered in connection with high rates of suppressed malarial infection that sub-inoculations prove that M.T. infections can be transmitted by injection of blood on the seventh and ninth days after mosquito-borne infection of volunteers taking atebrin, even though no parasites appear in the blood. An atebrin-resistant strain of *P. falciparum* was demonstrated in the area; it is likely that this characteristic was not firmly or long established, but this is unproven. Its mode of origin is not certainly known: epidemiological evidence indicates that it is very improbable that it arose among Australian troops who were not taking full doses of atebrin, but rather among Japanese. Rigid discipline was imposed, particularly in the taking of atebrin: it is possible that psychologically such discipline can be too rigid. Nevertheless some breakdown must have occurred: it may or may not have been greater than the degree occurring elsewhere. The proportion of men with overt malaria infected by the atebrin-resistant strain is uncertain. The elaborate and time-consuming nature of the very thorough and accurate researches made could cover only a small number of selected patients. This difficulty is innate in the investigation of

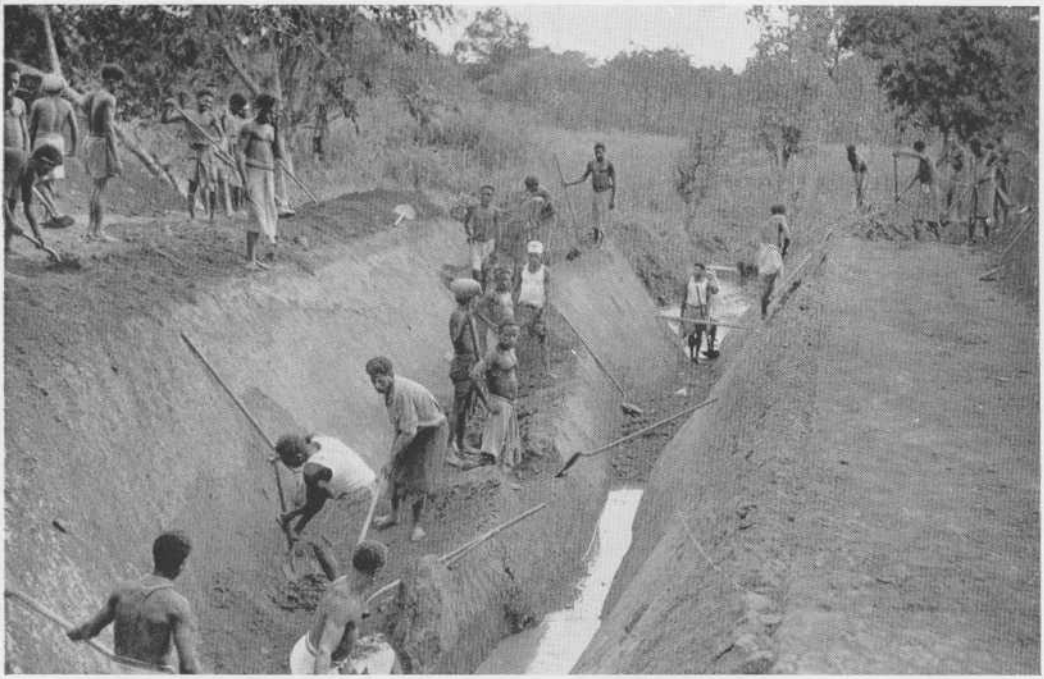


Malaria control—swamps to be drained near Port Moresby, New Guinea.



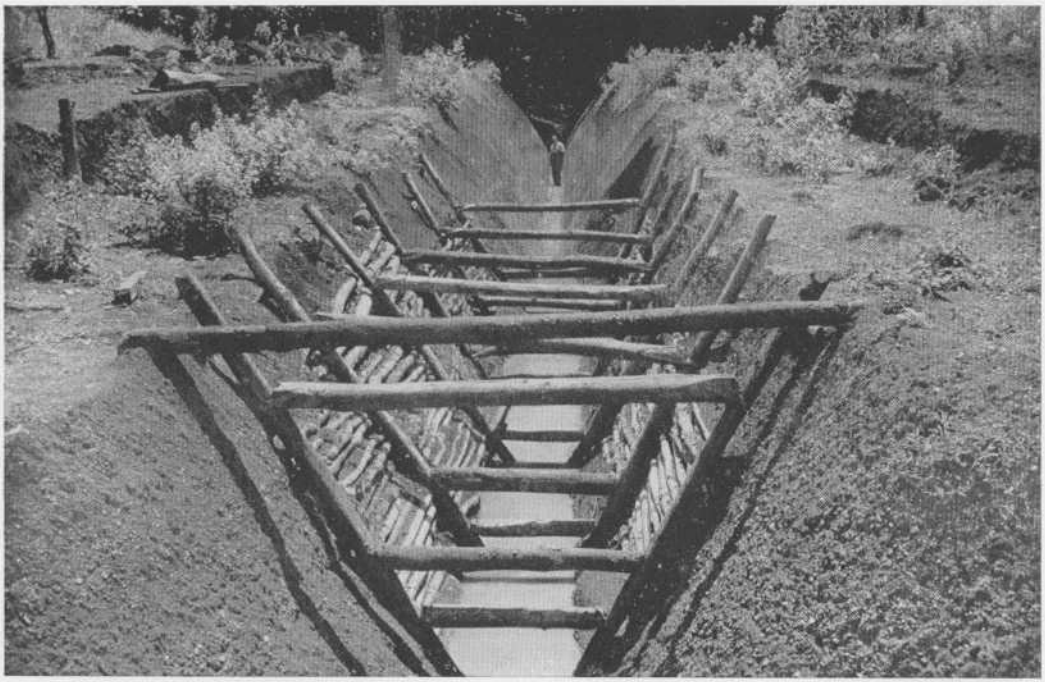
(*E. Ford*)

Draining a swamp near Port Moresby, New Guinea.



(Australian War Memorial)

Draining a swamp near Port Moresby, New Guinea.



(E. Ford)

Malaria prevention—canalising stream.

epidemics of acute disease. However, it seems certain that the atebrin-resistant strain was not the prevalent strain in the area.

On the credit side are the facts that the division was able to carry out its assigned tasks with complete success and that atebrin was successful in suppressing overt malaria in two-thirds of the force. The lessons of the Aitape-Wewak campaign are the military necessity for continued striving to attain perfection of personal as well as mechanical control of disease, realisation of the great number of variables involved in unravelling the scientific problems encountered, the need for constant local technical investigation in every operational area, and the desirability of having at hand more than one reliable suppressive drug for use in the field.

SUMMARY OF THE WORK OF THE MALARIA RESEARCH UNIT

A brief summary may now be given of the work done at the Cairns Medical Research Unit, pertaining to malaria in general.

Some of the already known facts about malaria were confirmed. A test of latent malaria was necessary in order to establish whether volunteers apparently cured of malaria were completely free of infection. For this purpose a larger amount of blood was used for sub-inoculation tests than the usual 10 cubic centimetres: instead 200 cubic centimetres, some 4 per cent of the blood volume, were given usually by direct transfusion. In *falciparum* infections sub-inoculations produced malaria in a fresh volunteer within twenty-three days if latent infection was present. In *vivax* infections this could not be relied upon, since the cycle during which tissue forms of parasite exist (in distinction to those found in the blood) is much more persistent in this form of the disease.

The possible existence of natural immunity was also investigated in volunteers who failed to contract malaria when exposed to infection. Intramuscular injection of a determined dose of parasites from a malaria donor never failed to produce disease, thereby excluding the possibility of premunity in the donor and natural immunity in the second volunteer. No evidence of natural immunity was found in these experiments. The results of sub-inoculation were also used to investigate the erythrocytic and exo-erythrocytic forms of parasite. It was found that if a volunteer is bitten on one arm by a mosquito carrying either *P. vivax* or *P. falciparum,* blood taken from the other arm after seven minutes will infect a fresh volunteer, proving that sporozoites are still in circulation. In one instance direct transfusion of 500 cubic centimetres of blood taken while biting was in progress produced malaria. After thirty minutes sub-inoculation was no longer effective: the sporozoites had left the blood. This gives some idea of the time taken by the sporozoites to become fixed away from the blood stream in the reticulo-endothelial system, as is generally believed. After infection of a volunteer with *P. falciparum* his blood failed to transmit malaria till the seventh day when it was capable of infecting another volunteer, in spite of the fact that for one to three days after no parasites could be found in thick films. The same held for *P. vivax,* but here the

blood was incapable of transmitting the infection for eight days. In *vivax* infections prolongation of this period of non-infectivity of the blood could be produced by the administration of plasmoquine. This is believed to be due to inhibition of the intracellular development of sporozoites and early tissue forms. Prolongation of the incubation of *P. vivax* could also be produced by giving a large daily dose of plasmoquine during a period extending from before exposure to five days after.

Fairley concluded from these experiments that support is given to the hypothesis that an exo-erythrocytic phase of B.T. is persistent, and that asexual parasites are shed from these tissue forms from time to time to cause relapses. The erythrocytic form in M.T. is vulnerable to atebrin, and the non-persistence of an exo-erythrocytic form is probably due to the tissue stage being a very brief one or vulnerable also to atebrin. Very sharply defined limits were found to the negative and positive sub-inoculation results, and it was suggested that if the tissue cycle was forty-eight hours there might be four cycles in *vivax* and three in *falciparum* before the erythrocytic forms were shed into the blood stream. These results also suggested optimum times for administering drugs under test for their action on sporozoites, early tissue forms and schizonts. An interesting clinical observation was made by R. R. Andrew at Cairns, that the first detectable sign in experimental mosquito-borne malaria was distinct tenderness of the liver on the ninth day after biting by infected mosquitoes.

Incidentally, during sub-inoculation experiments some valuable information was collected regarding the phase of the parasite on which a drug was acting. In connection with work done at Cairns on the cultivation *in vitro* of New Guinea strains of *P. falciparum* and *P. vivax* some observations were made on the behaviour of cultures exposed to the action of anti-malarial drugs. The second generation was not seen in *vivax,* and in *falciparum* this did not develop beyond large rings and amoeboid forms. Postulates made from this work have some bearing on the action of these drugs on the metabolism of the parasite, for example, the hypothesis that they prevent the use of pyrodoxine by the plasmodium. These studies at Cairns have borne fruit in further research since the war, particularly the demonstration of the tissue stages of parasite at the London School of Tropical Medicine and Hygiene.

ENTOMOLOGICAL RESEARCH

Further scientific observations had been made during 1943 and 1944 on the bionomics of mosquitoes, and in particular on their habits of breeding and biting. The latter was most important, and local observations were essential in new areas. An interesting and important finding about *punctulatus* was that intermediate types were found between *moluccensis* and *typicus varieties.* At a meeting of the Allied Conference in New Guinea discussion showed how unsafe were generalisations based on studies in a single locality. The U.S. Navy malariologist at Guadalcanal found there that the conditions with regard to *punctulatus* were almost the reverse of those found in New Guinea. In the Solomons intermediate types had not

been recognised, yet at Aitape there were few pure strains, the majority being intermediates. The importance of exact local observations was proved again and again.

Scientific research was also being pursued in the field. In the course of local surveys a considerable volume of useful entomological work was produced, though this was always related to the military problems in hand. In addition, a whole section of the Division of Economic Entomology of the Council for Scientific and Industrial Research in charge of Captain D. F. Waterhouse was made available for biological and chemical studies of control methods. Arrangements were also made for systematic identification of mosquitoes to be done by D. J. Lee at the Department of Zoology in the University of Sydney, where the staff of the School of Public Health and Tropical Medicine also gave assistance.

Besides the work already mentioned Major A. R. Woodhill carried out investigations on the subspecies of *Anopheles punctulatus*. The existence of what appeared to be a hybrid emphasised the value of study of the exact habits of a vector in a given locality. Contributions made to the meetings of the Allied Malaria Control Conference, such as those of Captain D. O. Atherton and Lieut-Colonel Orth (U.S.A.) helped to spread information concerning habits of flight, breeding and biting of local mosquitoes and its application to problems of control. Studies were made on the behaviour of adult anophelines at Cairns, and various places in New Guinea by F. H. S. Roberts and P. J. O'Sullivan, and I. M. Mackerras examined the "vector qualities" of Australasian anophelines. This latter study dealt with the susceptibility of infection, abundance, association with man, avidity for human blood and length of life. *Anopheles punctulatus* (*typicus*) was outstanding in all these qualities and was therefore the most dangerous vector, next to which came *Anopheles punctulatus moluccensis,* more correctly styled *"farauti"*. Under favourable conditions *A. annulipes, bancrofti, subpictus* and two varieties of *amictus* were potential vectors, and unknown, but the most locally significant were *A. meraukensis* and *novaguinensis.* Considerable research was also carried out in the field of methods of control.

CLINICAL INVESTIGATIONS IN ARMY HOSPITALS

Turning to clinical considerations we may note that the resources of army hospitals were used to study and compare various methods of treatment with particular reference to their effectiveness in relieving fever and clinical symptoms, and in clearing the blood of parasites, their toxic properties if any, and their capacity to control relapses. Amongst the combinations tested were the following:

1. Quinine 10 grains and plasmoquine base 0.1 gramme three times for ten days. Two hundred and eighty-eight showed a relapse rate of 7.3 per cent: more patients who had not had previous courses of treatment seemed to relapse. Mild nausea and occasional vomiting were observed in a few patients, but only in two (members of the nursing service) were these symptoms severe.

2. A special course of quinine, atebrin and plasmoquine base was compared with an intensive atebrin course. The doses were respectively (1) quinine 30 grains a day for three days and atebrin 0.9 gramme, 0.6 gramme each one day, 0.4 gramme for three days, and plasmoquine 0.3 gramme daily for three days; and (2) atebrin 1.2 grammes for one day, 0.8 gramme for one day and 0.4 gramme four days. 2,088 patients were studied who had an average of slightly more than one attack previously treated, acquired in New Guinea. Clinical response was good with each method, and no distinction could be drawn. The rate of parasite clearance was much faster with the intensive atebrin course, but there was no significant difference in the recrudescence rate, which was low (0.2 per cent to 0.5 per cent). The latter course enabled patients to leave hospital more quickly, but its toxic effects were more pronounced.

Excessive vomiting was more frequent with intensive atebrin therapy and 1 per cent of the patients had a confusional state, which was severe in three cases. This aspect was also studied at another hospital, and is discussed later.

3. Observations were made on the blood levels of quinine and atebrin in the "Q.A.P." intensive course used in these experiments. Very satisfactory concentrations were found, the average quinine level was above the effective therapeutic level (5 microgrammes) for six days, and more than double this during the first three days. Parasite counts rapidly fell and were negligible by the third day. The same was true of the atebrin levels, 80 microgrammes at least for six days, and 125 on the third day, the effective therapeutic level being taken as 30 microgrammes.

4. Groups of over 1,000 patients with malaria were compared to test the results of standard malarial treatment (quinine 30 grains daily for three days, atebrin 0.3 gramme daily for five days and plasmoquine base 0.03 gramme with 15 grains quinine daily for three days) and a moderate atebrin treatment (0.6 gramme daily for two days and 0.4 gramme daily for four days).

No striking difference was found in the clinical response, or in occurrence of recrudescences. Parasite clearance was better with the atebrin treatment, though control of fever was identical. This apparent discrepancy was probably due to the fact that there the concentration of parasites was often too low to cause fever. Toxic effects with both methods were inconsiderable.

It was evident from this carefully controlled work that the usual standard methods were efficient, and that abbreviated courses in which higher atebrin dosage was used, were quick and effective. The position about relapses was not so sure, as the determining causes, if any, were obscure. However, the standard course of quinine, atebrin and plasmoquine followed by a maintenance course of atebrin seemed to give results as good as any other method.

THE INTRODUCTION OF "PALUDRINE"

The advent of "Paludrine" changed the whole outlook, though the proving of this drug was completed too late for it to be used in extensive field trials under operational conditions. The Medical Research Council in Great Britain which had controlled malarial research there, arranged for clinical trials of promising drugs. In 1944 F. M. Rose and F. H. S. Curd, working in the laboratories of Imperial Chemical Industries, synthesized two very promising members of a new series of anti-malarial drugs. D. G. Davey found that these not only killed malarial parasites in the blood of birds, but acted as a causal prophylactic, this is, could prevent infection from being established. The better of these (code name M 4888) was submitted to clinical trials early in 1945, and its pharmacology was studied. The Medical Research Unit at Cairns was asked to investigate its prophylactic and therapeutic action on human volunteers infected with South-West Pacific strains of malaria. Later the drug was styled "Paludrine": some confusion occurred about this name which had already been used for the less successful compound M 3349. The name has since been adopted for the drug M 4888, which is also called "Chlorguanide" in U.S.A. Since the war the name "Proguanil" has been used in Britain.

Tests were carried out at Cairns on some 200 volunteers with experimentally-produced infections, and clinical trials were made on soldiers suffering from malaria contracted in the South-West Pacific Area. Paludrine was proved to destroy parasites of malignant malaria inoculated by mosquitoes before they passed into general circulation. One gramme of the drug taken by mouth by a volunteer three hours before being bitten by a mosquito carrying *P. falciparum* would prevent him from developing malignant tertian fever. A dose of 0.1 gramme given on the second day and for three days thereafter would also prevent the disease from developing. Thus paludrine is a true causal prophylactic for malignant tertian malaria. Complete suppression of M.T. was achieved in volunteers by administering 0.1 gramme daily, no matter how many infective bites they received or what exertion, fatigue or cold they endured. Sub-inoculation experiments proved that the infection was cured. Thus paludrine was able to destroy both the erythrocytic and exo-erythrocytic forms of *P. falciparum.*

With benign tertian malaria paludrine was completely successful as a suppressive, and inoculation of the blood of a volunteer infected with *P. vivax* did not produce malaria in another volunteer who was taking paludrine. Thus the drug acted as a partial prophylactic, but relapses were prone to occur on cessation of ingestion of the drug, as with atebrin, since the exo-erythrocytic forms of the parasite still survived.

When used in the treatment of frank clinical malaria, paludrine controlled both M.T. and B.T. infections as efficiently as quinine and atebrin. Culture experiments by Captain R. H. Black showed that the drug inhibited nuclear division of *P. falciparum* grown *in vitro.* Consequently the drug acted more slowly than other drugs, especially quinine, and allowed a

rigor to occur before control of the parasite was gained. The minimum effective dose necessary to control fever was extraordinarily low, one dose of 0.1 gramme. No comparable schizontocidal effect had been observed in other drugs. Observation of patients treated showed that 64 out of 65 patients with M.T. were cured by taking 0.3 gramme a day for ten days. Relapses were not entirely controlled, but the experiments indicated that they were reduced in number and could be suppressed by one or two tablets of 0.1 gramme per week.

The atebrin-resistant strain described above was found to be extraordinarily susceptible to paludrine, for 0.025 gramme was found to suppress the disease in infected volunteers. Further experiments indicated that a combination of paludrine and plasmoquine might be potent in acting on the persistent exo-erythrocytic forms of *P. vivax*. Gametocytes were studied in respect of their vulnerability to paludrine. The drug did not inhibit the usual gametocyte wave, which was observed after the administration of 0.3 gramme daily for ten to fourteen days. Though no obvious change was produced in the gametocytes of *P. falciparum*, they were unable to infect a mosquito allowed to bite a patient taking paludrine. Even a single tablet of the drug taken by a gametocyte carrier an hour before he was bitten by a mosquito would prevent the development of oocysts in the insect's stomach; they formed but did not grow. Even traces of the drug in the volunteer's blood were sufficient to produce this effect, for the organism died off in the mosquito even up to ten days after paludrine administration had been discontinued. Similar results were obtained with *P. vivax*: gametocytes disappeared from the blood by the seventh or eighth day of treatment, and though they were unchanged in appearance the presence of paludrine in the blood as shown by M. J. Mackerras was associated with a remarkable carry-over which prevented the development of the oocyst in the mosquito.

Finally, in all the experiments at Cairns and in hospitals the drug showed a very low degree of toxicity, and its therapeutic dosage range was wide. It had the further advantage that it did not stain the skin.

Other drugs were tested at Cairns. For example, SN-6911 was tested and the results presented to the National Research Council U.S.A. in November 1944. This drug did not stain the skin or upset digestions, suppressed and cured M.T., but did not act as a causal prophylactic. *Vivax* infections were suppressed by it just as by atebrin. However, no drugs tested gave the performance of paludrine.

FURTHER EXPERIENCES IN THE TOXICITY OF ATEBRIN

More anxiety was probably felt in the beginning about the possibility of atebrin having toxic properties than later, when definite knowledge had accumulated. In spite of a wide use of atebrin in the treatment of malaria before the war, it had not been employed on a large scale over extended

periods of time as a suppressive. Experience with all drugs has proved that time is an important factor in producing toxic effects.

Toxic hepatosis was at first thought to be a possibility, owing to the accumulation of atebrin in the liver, but lesions of that organ were very rare. Aplasia of the haemopoietic system was also thought possible, and though this occurred it was also rare.

Skin lesions, whose possibility was also suspected owing to the fixation of variable amounts of dye in the skin, were by far the commonest manifestations of atebrin intoxication, yet these too occurred only in relatively moderate numbers, not significant when compared with the necessity of using the drug. Toxic confusion due to atebrin also occurred rarely. It was only in the later part of 1943 and beginning of 1944 when cases of a lichenoid affection of the skin appeared in any number. In view of the great military importance of a retention of faith in atebrin by the soldiers the patients were handled very discreetly; dermatologists agreed that this was a lesion resembling *lichen planus,* but of a type not seen in civil practice. Fuller account of this condition is given in the section on dermatology; here a brief description will suffice. The skin pigmentation caused by atebrin varied greatly. The skin had a curious greenish yellow tinge best seen on parts not sunburnt. In some persons deep pigmentation of a brownish colour occurred which faded very slowly on suspension of atebrin. Such persons were not necessarily affected by any skin disturbance. Pigmentation of the conjunctivae was as a rule minimal or absent, but it sometimes occurred, causing a deep pseudo-icteric tinge. The mucosa of the mouth was sometimes stained with dark patches of bluish or brownish colour, and occasionally the nails sometimes showed bluish pigmentation. Hypertrophic changes occurred at times in the skin of the palms and soles. When the lichenoid eruption was well established horny thickening of patches of skin on the trunk and elsewhere were an occasional feature, to which was added in a few instances a deep almost black pigmentation. When it became evident that a lichenoid eruption was an entity appearing in many parts of the tropical operational areas, it was naturally connected with the wide and continued use of atebrin, particularly in higher dosages. Yet it occurred only in a minority of persons taking continued large doses, that is, 0.2 gramme daily. Cases such as that described by Lum illustrate this. A man who had taken 0.1 gramme a day for six to nine months died from a rapidly developing hepatitis in four weeks. He also had a typical "tropical lichenoid" eruption.

This eruption assumed different characters, but there were constant basic features. Papules or plaques appeared, erythematous or violaceous with some hypertrophic reaction, scaly, or even verrucous. Pigmentation was common, so too were atrophic manifestations such as deficient sweating and alopecia. Mucous lesions were seen in the eyes and mouth. In some patients fissuring appeared, with eczematous weeping. Rarely a severe bullous form occurred, somewhat pemphagoid in type. The trunk was less affected than other parts as a rule, but the limbs, buttocks, genitals, feet, hands and neck were commonly involved. Itching was sometimes

slight, but sometimes quite troublesome. The exudative lesions rarely were precursors to a general exfoliative dermatitis. It should be pointed out that exfoliative dermatitis as a lesion *per se* was certainly due to a number of causes. It was seen sometimes at the close of 1942 before atebrin was used as a suppressive; a few such conditions were probably due to sulphonamide drugs, the cause of others was unknown.

Perhaps "wishful thinking" led at first to some reluctance to incriminate atebrin, even if such admission was made with great secrecy, but there can be no doubt that atebrin was at least the chief cause. Obviously some degree of idiosyncracy must have been necessary. Other possible factors suggested were a hot moist climate, nutritional deficiency, contact irritation, photosensitivity or some unknown infective agent. Some of these could be readily dismissed. Cases occurred on the Australian mainland in men who had been in a good cool climate for some time, not unduly exposed to the sun, and taking a satisfactory diet. While there may have been some other factors, not omitting the influence of the central nervous system on skin sensitivity, there was only one common factor, the taking of atebrin.

Skin patch tests with atebrin sometimes caused reactions but these were also seen in controls, and were little help in diagnosis. Extended investigations were not carried out, but the general results of observation concorded with the findings and opinions of work done elsewhere. By the end of 1944, for example, the Malaria Research Unit of the 3rd Medical Laboratory, U.S.A. Army Medical Services, had established that in this skin condition the mean plasma atebrin level was higher than that given by a weekly dose of 0.7 gramme, the skin atebrin concentration did not differ from that of persons with no skin lesions, and there was no demonstrable relationship between dietary insufficiency and the lichenoid disease. The experience quoted by Williams is significant. Amongst 18,000 New Zealand troops in Fiji, Tonga, New Caledonia and other Pacific Islands free from malaria no lichenoid was seen, and no atebrin was taken. Among the men in malarious islands, such as the New Hebrides, cases of lichenoid occurred within two and a half months; the men here were taking 0.6 gramme atebrin a week. In general improvement took place following withdrawal of atebrin, but after a latent period. Where atebrin medication was continued for treatment of malarial fever, recrudescence of the skin lesions was not always observed, but over longer periods of time it appeared that the generalisation was true that improvement was quicker and better after atebrin was suspended.

When this eruption was most common in the Australian Army skin diseases as a whole were also most prevalent, but it must be conceded that where the risk of malaria was greatest conditions productive of skin disease were also present. Improvement was noticeable about the time that the atebrin pigmentation began to leave the skin. No special treatment seemed to be effective. The time taken for full recovery varied to a good extent according to the previous duration of the dermatosis; long established lesions might take a year before they were completely resolved, but those

less firmly established sometimes cleared up completely in three or four months.

Reverting to hepatic lesions, acute toxic necrosis of the liver is occasionally seen in any community, but the number attributed, and probably correctly so, to drugs has grown of recent years. Since liver atrophy and aplastic blood disorders have rarely occurred in the army, but have been seen in connection with tropical lichenoid dermatitis, it is likely that this association is more than coincidental.

Psychoses related to high atebrin dosage have been mentioned previously. The episodes observed in hospitals during tests of high atebrin therapy were usually mild, and though varied in type, were confusional in general pattern. One patient had a maniacal outburst and two had epileptiform convulsions. Most of these patients had psychological defects of temperament, evident from their record, past history and subsequent examination. The condition was not constantly related to the atebrin blood level, and no parasites were observed in the blood during the episodes. There was no evidence during these tests that ordinary suppressive doses of atebrin, 0.1 gramme a day, caused any psychic disturbance. D. M. Ross described seven cases regarded as confusional states due to atebrin intoxication, seen in the psychiatric wing of an Australian general hospital, which treated 331 psychotic patients during the period under review. The pattern of symptoms was unlike the recognised psychoses; the patients seemed to have insight into their own condition, were worried by their peculiarities of behaviour and usually sought advice spontaneously. A confusional state allied to disordered action was the usual type seen. This always began within three weeks of commencing suppressive atebrin, especially when a larger dose was ordered to build up the blood level quickly. Temporarily raising the daily dose from 0.1 gramme to 0.2 gramme caused no unusual effects, and there was no evidence of the standard dose of 0.1 gramme daily causing mental disturbance.

Euphoria associated with hyperactivity was not specially noted in this series, but was occasionally reported in others. Australian experience with atebrin has revealed very few instances of mental disturbances due to toxic action. Perhaps mild symptoms might have occurred rather more frequently in association with high dosage than official reports indicate, as some of these may pass unnoticed, but on the whole the incidence has been negligible. Gastro-intestinal symptoms have, as previously mentioned, been unimportant and only a rare cause of trouble during high atebrin dosage, and then as a rule transitory only.

THE VALUE AND TOXICITY OF PLASMOQUINE

The toxicity of plasmoquine was periodically a subject of discussion during the war. Despite reports of abdominal pain and of haemoglobinuria from overseas, especially associated with previous administration of atebrin, the Australian experience was not unfavourable. Extensive clinical investigation showed no cause of uneasiness about the drug, although occasional complaints of abdominal pain were made. For a long time

there was a belief that plasmoquine was toxic if taken while a therapeutic concentration of atebrin was present in the body. The original pause of a day or two between the giving of atebrin and plasmoquine in the standard course of treatment was later omitted with no bad result. An enquiry was carried out in a military hospital to see if patients taking plasmoquine immediately after atebrin suffered any symptoms such as abdominal pain, but it was soon found that questioning the men suggested the very symptoms which were being investigated. Undoubtedly a minority of people were somewhat sensitive to plasmoquine, and it is admitted that the margin between therapeutic and toxic doses is not great, but in Australian experience it has proved a safe and useful drug. No doubt was felt concerning its gametocidal properties. Before the war its gametocidal action on M.T. crescents was established: this was confirmed at Cairns. M. J. Mackerras showed that a single dose of 0.02 gramme completely sterilises all M.T. crescents in the blood within less than 24 hours. Australian experience also coincided with the general agreement in most countries that it has some action in controlling relapses. The value of a course of quinine and plasmoquine for relapses had been pointed out by Sinton in 1937; only later during the war did this receive attention which it merited. Nevertheless it was necessary at times to represent strongly the need for this drug which was of specific value and was also an important component of a standard treatment which, with occasional modifications for special purposes, gave excellent results throughout.

CLINICAL ASPECTS OF MALARIA

About the purely clinical aspects of malaria there is not much to be said, although individual differences in bedside manifestations are as characteristic of malaria as any other infective disease. The death rate was extremely low, less than 0.5 per 1,000 owing to prompt diagnosis and treatment, not to any mildness of the disease. It was the duty of commanders of army field medical units to ensure that all the medical officers on whom devolved the care of men with malaria should be certified as competent to make the microscopic diagnosis. Large numbers of technicians were similarly trained. Diagnosis of course cannot be made with certainty except from blood films, and there can be few Australian medical officers with tropical field experience in this war who were not familiar with the use of Field's stain on thick films. Chemical suppression by drugs made diagnosis more difficult, and the coexistence of dengue in some areas introduced another element of doubt, particularly where transport for the evacuation of sick was subject to delay.

The only types of parasite of importance were the *P. falciparum* and *P. vivax*. The *tenue* subvariety of *falciparum* was observed with some frequency among natives on the north coast of New Guinea, but no particular significance can be attached to this. *P. ovale* was occasionally seen. For practical purposes it was regarded as similar to *vivax,* and was not of importance, but the identification of the ornate trophozoites when stained by Giemsa or similar stain was of interest. *P. malariae* was so rare as to

be negligible. Nevertheless quartan infections were not infrequently seen in native children and a nephrotic type of nephritis was observed in at least one such child. The rarity of this parasite was in part due to its peculiarities in transmission.

The advantages in relegating to the clinical background the descriptions of the classic types of malarial fever have been mentioned before. This phenomenon should resemble the once well-known remissions of pernicious anaemia in one sense, that the disease should be recognised too promptly for them to be seen. The different clinical patterns of M.T. and B.T. sometimes enabled a bedside distinction to be guessed, but minor points such as the occurrence of herpes were unimportant compared with the warnings of a conscience alive to the facts of pathology which reminded the medical officer of the facts, such as the capacity of M.T. to thrust B.T. aside when break-through of suppression occurred, and the real and great dangers of the former infection. Patients with M.T. were not necessarily very ill: it has been pointed out that in Aitape-Wewak mildness was a striking feature. But often such patients were very ill and showed those familiar multiform characters of severe infective illness which cause anxiety to a doctor or a nurse, and which are understated by the medical slang phrase that the patient "was very toxic". Fever which was not promptly controlled, or evidence of hyperinfestation, or suggestions of a possible metastatic complication of M.T. fever were indications for the use of the intravenous injection of 10 grains of quinine. The immense value and the safety of this measure are firmly established in the minds of those who had to treat large numbers of men very ill with malaria.

Of all the complications of *falciparum* infections cerebral malaria and the extremely severe infections just described were most common. The latter, of course, is not truly a complication. Cerebral malaria took all its usual forms, in particular coma and convulsions. Care was taken not to overdo treatment, a real danger which should not occur. The capacity of cerebral malaria to strike suddenly was not infrequently demonstrated, and illustrated, too, the imitative nature of the disease. In such cases treatment was not allowed to wait upon diagnosis. Cerebral malaria was fortunately infrequent and owing to suppressive atebrin and prompt treatment the death rate was low. Medical officers of the 8th Division experienced cerebral malaria under unfavourable circumstances. In Changi it was uncommon; but was much more frequently seen in Thailand and still more so in Burma. In Burma Hunt described two chief types, one with violent delirium and the other with drowsiness increasing to coma. Lumbar puncture was tried therapeutically, but withdrawal of spinal fluid had no effect on convulsions; the pressure was never raised but was often low. In Changi neurological sequels such as aphasia with spastic palsy of the right arm, and heminanopia were seen.

Abdominal forms of malaria were less common, but they occurred. In one instance in the Sanananda sector a medical officer asked for transport to move a patient whose symptoms suggested an abdominal emergency.

As it was night and all movement was difficult and at the time dangerous, the trial of intravenous administration of quinine was suggested. In the morning the man was well. Symptoms of shock with sudden onset and no elevation of temperature were also encountered. These so-called "algid" types have been attributed in some instances to coronary vascular lesions due to *P. falciparum* and these have been described at autopsy. No certain demonstration has been made in this series.

Sudden convulsive seizures occurred on all tropical fronts and aroused much interest. While some were undoubtedly due to malaria, others were not, so far as could be determined. Typhus was a probable cause in a few cases, but in others no explanation could be given save that they may have been true epileptiform seizures occurring as a single phenomenon in an exhausted individual. Death occurred in a few instances, but autopsy did not always give the reason. Medical officers were informed that where the facilities for full autopsy were inadequate, smears of the cortex could be made on slides and examined for parasites. This condition is discussed in the section on nervous diseases.

Jaundice associated with malaria always suggested the possibility of a relatively severe M.T. infection. Opportunity occurred during the first Papuan campaign for a study of this problem, as jaundice was then not uncommon in troops returning from the coastal areas. Undoubtedly infective hepatitis was occurring at this time, and on occasion there was reason to believe that the two infections coexisted. Indeed at this time the old advice never to diagnose two diseases in one patient was misleading and often proved fallacious. There was a gradation of severity leading up to the more serious M.T. infections in which the appearance of urobilinogen and then bile in the urine would be followed by haemoglobinuria. When the latter occurred it was regarded as threatened blackwater fever and treated accordingly. With the realisation that a degree of hepatitis was invariably present, came the doubt whether atebrin might be less easily dealt with by a damaged liver, but no evidence of this was found. As a matter of fact many such patients were regarded as showing indications for parenteral administration of quinine. In a different category were the patients with malaria who were deeply jaundiced but who were clinically only slightly ill. These in many instances had a virus hepatitis as well as a controlled malaria.

BLACKWATER FEVER

Blackwater fever was seen with increasing rarity as time went on. Numbers of men in whom haemoglobinuria was observed and who were treated as possible sufferers from early blackwater fever recovered promptly and were never classed other than as malarial subjects. Whether less careful handling and less forethought might have swelled the numbers of blackwater fever or not was a matter for conjecture. Evidence of haemolysis was regarded as a sign of great potential danger. A technical instruction was issued in the army based on the facts that death in blackwater fever was most commonly due to anuria and uraemia, and that

haemoglobin can be excreted by the kidneys with little disturbance of structure or function when the urine is alkaline in reaction, with pH 8.0. In order to stop the conversion of haemoglobin into methaemoglobin and acid haematin in the kidneys and to obviate mechanical blackage of the renal tubules rapid alkalinisation of the urine was advised. Sodium bicarbonate in saturated solution and 4 x molar sodium lactate solution were combined in ampoules of 10 cubic centimetres and two such ampoules were injected into a vein at once and at intervals of a quarter to half an hour as required. Glucose-saline solution was used to dilute the alkalies if immediately available. Alkalies were also given orally if tolerated. The same treatment was recommended for incompatible blood transfusion, fortunately exceedingly rare in war experience.

Treatment by alkalisation has not been without its critics who, like Maegraith and Havard, have pointed out that acid haematin is most easily precipitated in a slightly acid medium and that anuria may begin while the urine is alkaline. Alkalosis and alkaline urine do not necessarily coexist. However, without too great an insistence on mechanical theories of anuria, which are surely not the whole story, there is reason to believe that whatever may be the precipitating cause of the blood crisis that determines blackwater fever, red cell equilibrium seems to be favoured by alkalisation. As with other forms of the lower nephron syndrome, early action is imperative. The service practice was one of caution on the whole, both with regard to the dosage of alkalies and the use of blood transfusion. It was felt that the latter had its place if blood destruction was severe and if great care was taken both with cross-matching of the blood and with the conduct and close supervision of the transfusion. The official instruction gave warning of the risks of producing alkalosis and of the need for watching for signs of tetany. Blackwater fever in service practice has been an excellent example of preventive medicine, since its existence was reduced to a very low figure, especially in the later years of war, and insistence on prompt and early treatment produced what was often anticipatory action. Recovery from established anuria is recognised as rare. The traditional association of blackwater fever with quinine was not always borne out in service experience: several cases have been seen in which no quinine had been taken before the onset of haemoglobinuria, but only atebrin. On the other hand instances occurred in which the patient had been taking quinine as a suppressive. Blackwater fever was observed on one occasion in a volunteer patient taking plasmoquine experimentally.

Anaemia was common in some degree after severe attacks of malaria, but did not necessarily demand special treatment. A healthy man after a sharp attack of M.T. would soon recover with a period of convalescence on good diet. But with the added factors of prolonged exposure to fatigue, and of a monotonous diet, and probably repeated malarial infection a frank attack would reveal an anaemic state needing treatment. Early in 1943 this was frequently found, and in various phases of the war also. The existence of hookworm infestation was an additional cause of anaemia, so too was dietary deficiency. The diet in operational areas was often

lacking in variety and in fresh components by the time it reached the fighting soldier, particularly in the early periods. Even in hospitals on the mainland except in large centres it was difficult to obtain fruit and fresh vegetables. In one hospital in Queensland in a series of 300 men who had just completed treatment for malaria contracted in New Guinea the mean haemoglobin value was below 13 grammes, and about one-third of the men had a value of 12 grammes or under, the normal average being 15.4 grammes. At the time scale preparations of iron were restricted in output, and ferrous salts were also far from plentiful. With severe anaemia transfusion of blood was the quickest method, but this was seldom necessary. It was, however, of great value for some of the debilitated men arriving in Moresby from the Kokoda trail.

A rare but serious complication of malaria was rupture of the spleen. On occasion this has happened spontaneously while the patient was at rest or even in hospital. Hughes and Niesche described one case in which the patient vomited and collapsed: he had pain above the left clavicle (Kehr's sign) but no rigidity. Pullen, Bowden and others have also reported cases occurring in men who had B.T. In several of these death occurred. On one occasion spontaneous rupture apparently took place during the night in a soldier on leave in an Australian city, who died before anything could be done for him. A possible precursor to rupture of the spleen was described by Andrew, who studied ten men who had what he considered a spontaneous subcapsular haemorrhage. Sudden severe pain was felt in the left upper quadrant of the abdomen with local tenderness and muscular rigidity lasting some days or even weeks. None were submitted to operation, no abnormality was found in the thorax, and all recovered. It seems unlikely that the syndrome was due to an infarct in the spleen because no such history is associated with infarction in conditions where it can be proved *post mortem*.

In 1942 the growing number of cases of malaria introduced the occasional problem of false positive serological reactions for syphilis sometimes observed in the serum of patients with malaria. An army technical instruction was issued on this subject, which stated that the incidence of frank reactions was about 10 per cent, and of doubtful reactions about 25 per cent. Such reactions were observed with all the usual complement deviation and precipitation tests in common use, and lasted for several months. Therefore a warning was given that immunological evidence of syphilis in patients with malaria was not necessarily trustworthy. The Kahn verification test was carried out at headquarters in Melbourne as a means of distinction from syphilis, but was not found of significant value. Actually in field practice not much difficulty arose from this fallacy. Cox and Durant made some observations on these tests in connection with malaria and found that there was little risk of calling malaria syphilis if repeated examination was made at intervals by both Wassermann and Kline techniques. They could detect no relationship between "false positives" and relapses, and could not differentiate between false and specific reactions. Francis and Wannan also found that simultaneous observation of Wasser-

mann and Kline tests enabled the serological distinction to be made between malaria and syphilis. (See section on venereal diseases.)

TRANSMISSION OF MALARIA BY BLOOD TRANSFUSION

Difficulties with blood transfusions from donors possibly suffering from latent malaria have been mentioned previously. A technical instruction was issued late in the war on this subject as it was realised that increasing numbers of men with latent or relapsing B.T. malaria would be potential blood donors in both military and civil communities. The instructions pointed out that when blood containing malaria parasites is injected direct into the circulation of a person with no premunity to that type of parasite the recipient usually has a rise of temperature within twenty-four hours. This fever is mild and transitory if parasites are scanty in the transfused blood, but it recurs after a few days. The danger that *P. falciparum* might be transmitted thus was emphasised, especially when the recipient was already suffering from a condition which of itself might cause fever, such as a septic wound. Available evidence indicated that blood infected with malaria cannot be made safe for transfusion either by the addition of quinine or by cold storage. Fortunately, however, trophozoite-induced infections are easily cured, and even B.T. does not recur if a course of treatment is given, in contrast to the history of sporozoite-induced infections. In general the advice given was if possible to use blood from donors resident in a non-malarious area. Where this could not be done, careful selection of donors was advised, and thorough examination of thick films of blood. Before a transfusion was undertaken in a malarious area, it was important to ensure that the donor had been taking suppressive treatment and advisable if time permitted to give him 0.3 gramme of atebrin four hours before blood was taken. The recipient of such a transfusion was given continuous suppressive atebrin, beginning with the therapeutic dose if previous administration had been irregular. Any suspicious sign or symptom was an indication for examination of blood films, and if *P. falciparum* was found or even suspected, intravenous quinine was administered.

Braithwaite in recording experiences of transfusion in highly malarious areas (Aitape-Wewak), compared the results of using blood from local donors and stored blood. Stored blood was brought by air and road from Australia, and by the time it reached the forward area, though not haemolysed, caused an undue proportion of reactions. Therefore its use was abandoned. With careful selection and premedication of donors, giving atebrin as a routine measure to the patients and following the transfusion with a full therapeutic course, satisfactory results were attained. Here not only donor but patient was probably already infected, and despite precautions a number of patients contracted overt M.T. The invariable use of a routine high atebrin therapeutic course solved this problem in an area where parisitaemia was so common that *P. falciparum* was found in the blood of fourteen out of forty apparently healthy soldiers, including combatant and medical officers.

CRITERIA OF CURE

A few points remain to be mentioned connected with the clinical aspects. The criteria of cure adopted underwent alterations corresponding to changes in circumstances. For some time blood films were examined at the conclusion of treatment, but this practice was discontinued as it was seldom of value and threw a burden on the pathological services. A single thick film was therefore examined on the third day after the end of treatment, and if possible also on the fourteenth and twenty-first day. At the end of 1942 a maintenance course of atebrin was introduced, consisting of 0.1 gramme for six days in each week for six weeks. This made the examination of slides unnecessary as a criterion of cure, and the practice was therefore given up. Similarly examination of the blood of troops returned from malarious areas was discontinued unless clinical symptoms were manifest.

RESULTS OF TREATMENT

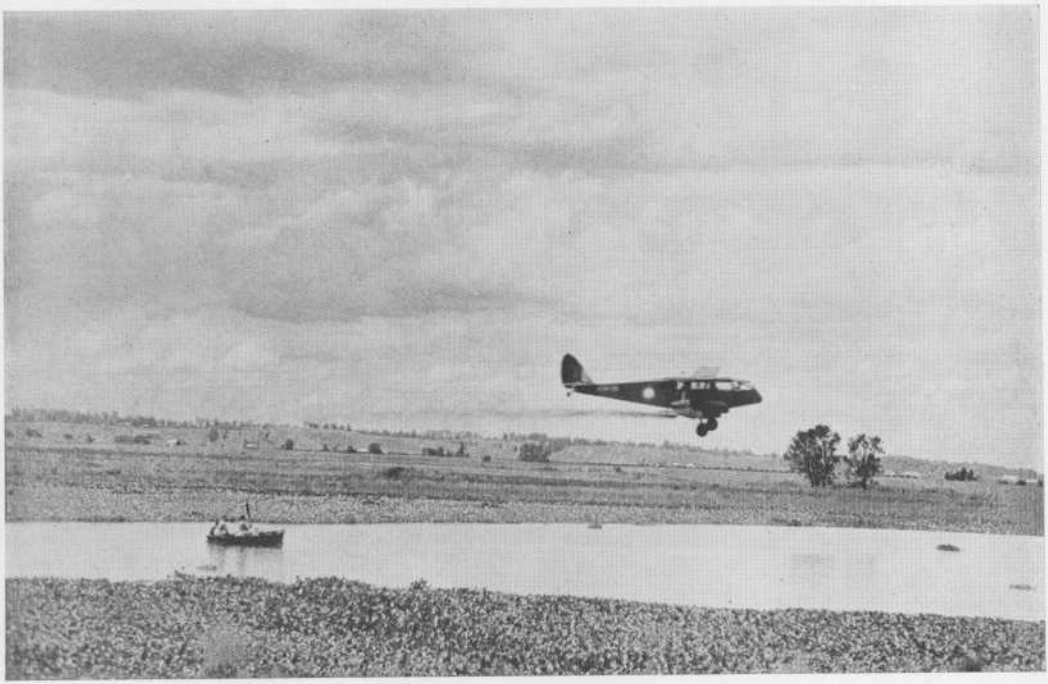
An army technical instruction which was of definite value to medical officers was one setting forth the results of malarial treatment. This embodied some of the findings of clinical research teams, and pointed out that the low death rate (under 0.5 per 1,000 for uncomplicated malaria) was due to early diagnosis, the use of intravenous quinine when indicated and suppressive treatment. Malignant malaria was found to recrudesce in 2 to 6 per cent and a second course of treatment had cured this minority in nearly every instance. The completed eradication of M.T. was the keynote of prevention of blackwater fever. Studies of relapsing B.T. infections indicated that only a minority of men would require more than two standard courses for clinical cure, and that not more than 5 to 10 per cent would be candidates for a chronic relapsing malaria. Latent malaria was common, chronic malaria was rare. Emphasis was laid on the need for prompt diagnosis and good treatment, for poor response to standard treatment was found to be associated with exposure to infection under conditions where these desiderata were not easily obtained, and where repeated infection would occur.

The various aspects of malaria in the civil population of Australia were carefully considered by the health authorities concerned. Indigenous malaria has already been discussed, with special reference to Queensland and the Northern Territory. The risk of exogenous malaria was minimal. As has been pointed out, in the potentially malarious areas of Australia the movements of malarialised troops were carefully controlled, and the vector position watched. Occasional cases of transmitted malaria were reported in different parts of Southern Queensland and New South Wales, but these were negligible. Contact with returned soldiers and civilians was established in several instances, and in one at least *Anopheles annulipes* appeared to be the vector. This occasional vector was also found breeding at one time in the neighbourhood of Concord Military Hospital in Sydney. As expected the transmission of malaria apart from the recognised areas was exceedingly rare. Among demobilised servicemen malaria has become



(*E. Ford*)

Spraying malarial breeding grounds with oil



(*R.A.A.F.*)

Mosquito control—spraying from aircraft.



(R.A.A.F.)

Aircraft spray equipment.

a diminishing problem, though in 1947 the Repatriation Commission found by questionnaire that in New South Wales it was still one of "appreciable magnitude". This was considered to be due to the failure of men to report for the correct sequence of pathological diagnosis, two weeks' treatment in hospital by paludrine and plasmoquine, and a follow-up course of paludrine for six months. This method has given encouragingly good results.

CONCLUSION

In conclusion it is of interest to look back over the six years during which malaria control played an increasing part in the campaigning of the Australian Armed Services, in particular the army. Several features of the constant struggle stand out. The organisation of control measures became more and more adequate and complete and rested on two foundations. One of these was the background of science, the other the principle that guidance was the role of the medical services, but that responsibility for carrying out measures for which disciplinary control was necessary rested with the combatant commanders and their deputies. The entomologist supplied information of a peculiarly technical and detailed kind, the malaria control specialist used this and other data in a characteristic mixture of entomology, hygiene and engineering, the malariologist combined the outlook of the doctor experienced in the pathological and medical aspects of malaria with a first-hand knowledge of military requirements. The clinical research teams patiently applied the complex techniques of combined biological and pharmacological experiment and submitted their results to field trial, the statistical experts collected and analysed figures and corrected unwarranted deductions, and the clinical workers at the bedside gave the benefit of their experience to patients and planners alike. This organisation was won by effort and trial not without opposition. As the result of these labours are there gaps in knowledge remaining, and are there weaknesses in the military method by which the knowledge is applied?

There are gaps of course. The loss of quinine to Japan was a blessing in disguise. Quinine still has first place as an antipyretic, lethal to the blood-borne cycle of the malarial parasite, and is unassailed for quick and reliable results in dangerous complications. But we have learned that it is a poor suppressive. Atebrin saved the day, and even though it yields the stage to paludrine and other and better anti-malarials, it has proved its ability to control massive infection, with a remarkably low price to pay in toxic reactions. Some of the doubts and difficulties with research on atebrin will be helpful in future work with other drugs. Since the introduction of the sulphonamides the estimation of blood concentrations has been firmly established as an index of effective dosage. The curiously unequal distribution of atebrin in the tissues of the body may be an indication of some of the difficulties in gaining certain knowledge of the mode of action of this and other drugs. The Australian research work used the generally accepted criterion of the plasma level of atebrin. Considerable variations are known to occur. Whether these are due to idiosyncracy, or to varia-

tions in absorption or whether there may be other occasional extrinsic factors such as occur in the peculiar conditions of jungle warfare, is not known with certainty. Factors governing degradation of atebrin in the intestine, and its absorption, may need further enquiry. Reid has suggested that variations in atebrin blood levels found in volunteers in certain stages of experimental M.T. infections may be related to transference from a storage depot in the liver. Plasma levels have been accepted as an expression of equilibrium of atebrin between the plasma and the tissues, though the validity of this has been questioned by some workers. Great advances are to be expected in the future in the attaining of accurate standards and measures of chemotherapy.

Of course there remain still the variables connected with human behaviour. It is evident that there are some disparities between biological human experiment in the laboratory which as yet cannot be reconciled. We cannot duplicate the effects of fear and anxiety by experiment, and exhaustion, with its physical and mental components, is not the same as fatigue. It was not found possible to produce break-through of malaria in volunteers in Cairns, though clinical impressions, statistically unconfirmed, strongly suggest that relapses may be induced by environmental traumata. There would be few if any who would deny that break-through of M.T. in the field does occasionally occur in persons who have unfailingly taken the dose of atebrin proved to be effective as a suppressive. Whether this may be an anomaly of absorption or due to some factor such as was present in Wewak, a relatively resistant strain of parasite, or to some other factor or factors unknown, we do not know. Under combat conditions in hyper-endemic areas such apparent anomalies may also be due to chronic and repeated infection associated with imperfect application of chemo-therapeutic suppression and personal protection. Again there must be some exciting causes for relapses of B.T.: though the existence of the tissue phase has been demonstrated since the end of the war the emergence of the parasites into the blood remains a mystery, yet it cannot be fortuitous.

Gunther has said that new concepts of malarial control alter our outlook on the problem: atebrin is passing, paludrine and its congeners rule in its stead, and chemical larval control may alter anti-malarial work radically. We now are better equipped than before in the war against this most destructive of protozoal diseases, but we still have to reckon with the recalcitrance of that possessor of high intelligence, man, who seems bent on destroying himself. It cannot be said that the very high overall rate of actual infection in the servicemen and servicewomen exposed to malarial hazards is entirely creditable. In theory we know how to prevent their infection, and how to suppress and partly to cure the resultant latent disease; and we have almost enough knowledge to cure the overt disease entirely and invariably when it occurs. In practice we have not successfully done all these things. Yet the manhood of Australia has suffered surprisingly little from the attacks of this dangerous enemy, and successful military operations have been made possible by the scientific knowledge

gained and its earnest application. Less spectacular, but highly successful, was the achievement of preventing the introduction of the island strains of malaria into the potentially malarious areas of Australia.

APPENDIX I.

September 1944.

General Routine Order.

By

General Sir Thomas Blamey, G.B.E., K.C.B., C.M.G., D.S.O., E.D.
Commander, Allied Land Forces in S.W. Pacific Area, and Commander-in-Chief, Australian Military Forces.

(a) COs will be held personally responsible for ensuring the strict observance of the instructions contained in this order and they, and all other officers, will at all times be vigilant and unremitting in the enforcement of such instructions.

(b) Neglect to comply with such instructions will be treated as a serious offence and will be punished accordingly.

(c) The occurrence of cases of malaria in a unit which has been directed to take the dosage of atebrin prescribed in this order will be regarded as *prima facie* evidence that the CO has failed to ensure the observance of such instructions.

APPENDIX II.

South-East Asia Command Headquarters.

From: The Supreme Allied Commander, South-East Asia.
Date: 14th February 1945. Ref.: SC5/398/E.
To: Commander-in-Chief, East Indies Fleet.
Commander-in-Chief, Allied and Forces, South-East Asia.
Allied Air Commander-in-Chief, South-East Asia.
Copy to: Commanding General, United States Forces, India Burma Theater.

Subject: ANTI-MALARIAL PRECAUTIONS:

I have already drawn the attention of Commanders-in-Chief to the importance of malaria discipline in my Directive of 1st January, 1944. Despite this the incidence per thousand men of malaria in South-East Asia Command is still very much higher than in the South-West Pacific Area. This I cannot accept.

2. Although there are certain factors operating in the South-West Pacific Area which render the task of controlling malaria in that area somewhat less difficult than in South-East Asia Command, the incidence of malaria in the South-West Pacific Area has been reduced, not by new method but solely by the high standard of anti-malarial discipline maintained in both the Australian and the American Armies, backed by comprehensive and extremely forceful routine orders rigidly enforced. Copies of these orders were forwarded in my letter PAO/MED/15.A of 26th September, 1944, with the suggestion that you should issue similar orders.

3. I now direct that if you have not already done so you will issue very strict orders on the lines of those given in Appendix A attached thereto. Owing to the varying problems of the Services regarding such matters as the definition of areas and the conflicting problems in dress, certain difficulties may arise in the interpretation of the orders attached hereto. If agreement cannot be reached locally, any such problems will be referred for decision at one of my meetings with Commander-in-Chief. I must emphasise that this is a matter of discipline designed to maintain fighting efficiency for which every Commander is personally responsible.

/s/ LOUIS MOUNTBATTEN,
Supreme Allied Commander.

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CHAPTER 8

THE SANDFLY—DENGUE FEVER GROUP

CHIEF among the short-term fevers of military importance are sandfly fever and dengue fever. Other more or less clearly differentiated epidemic infections may be grouped with these, sharing the same diagnostic difficulties, for they can be recognised only by the collective patterns of their symptoms, by their epidemiology and the presence of appropriate vectors, when these are known.

Sandfly and dengue fevers show many close resemblances, though there are some distinctive clinical features in each in addition to the difference in vectors.

1. SANDFLY FEVER

Experiences of the last war indicated that the disease would cause wastage of men for short periods, but the first epidemic in 1940 was more extensive than expected. This was due to the fact that the troops were in fixed training camps in which considerable constructional work was carried out, thus providing the vector sandflies with abundant breeding places. During the period from May to November 1940, 946 patients (15 per cent of the total admissions) were admitted to the 2/1st Australian General Hospital with sandfly fever, many others contracted the infection while in hospital, and many hundreds were held in the 2/1st Australian C.C.S. or in camp hospitals. In 1941, 5,717 men with sandfly fever were admitted to hospital and 1,306 in 1942. Thus there must have been at least 9,000 or 10,000 men treated for the disease in the Middle East, and to these figures must be added the unknown cohorts of those who kept on their feet or recovered after some period off duty in their units.

SYMPTOMS

The symptoms showed the variability characteristic of this group: the clinical picture seen even in different camps over the same period did not always correspond closely. The onset was frequently sudden with minor shivering or followed a prodromal period of twenty-four to forty-eight hours. During this period there were headache, pains in back and limbs and striking malaise with feelings of heaviness and fatigue. The appearance of patients with the established disease was often striking, the face being red, puffy and swollen, and the eyes engorged owing to conjunctival congestion. Pain in the ocular muscles often limited the eye movements and photophobia was troublesome. In some epidemics a crop of clear vesicles was seen on the back part of the soft palate. It was noted that this enanthem also appeared in the early stages of infective hepatitis, the early symptoms of which often resembled sandfly fever; perhaps this explained the claim of some observers that jaundice occurred occasionally in sandfly fever. In Cyprus, for example, jaundice was described in patients believed

to have sandfly fever. No catarrhal signs in the respiratory tract were found as a rule, but in some outbreaks in which such signs appeared it was not clear whether they were due to a pre-existing infection or to the disease. No rashes were described in most epidemics, but a faint macular rash was observed in a few instances in 1940, though in 1941-1942 in Syria as high a proportion as 10-15 per cent of patients were reported as showing sparse pink macules on the trunk. This rash was seen on the first or second day. A faint mottling of the protected skin was also noted sometimes during the early days of convalescence. In some series this appeared in some 40 per cent of patients. A few petechiae were sometimes found, chiefly about the lower limbs.

The fever usually warranted the name of "three day fever", but longer bouts were not infrequent, and secondary rises were sometimes seen. A relative bradycardia was almost the rule, and a slow pulse was often noticed also during convalescence when a rate of 50 was not uncommon. Swelling of lymph glands was not observed in some outbreaks, but in later epidemics it sometimes occurred. Splenic enlargement was unusual, but did occur apart from other infections. Anorexia was striking, and nausea and vomiting sometimes occurred. Occasional diarrhoea was noted for which no other bacteriological cause was found. Drowsiness was extremely common, though restlessness at night was equally common. True meningeal irritation was probably uncommon, but resistance in the tender neck muscles sometimes gave that impression. In one series neck stiffness was reported in some 10 per cent of cases, though the cells in the cerebro-spinal fluid did not exceed 10 per millilitre. In another series increase of pressure in the cerebro-spinal fluid was found where neck rigidity was present, but increase in cells was only slight. The skin was often hyper-aesthetic on the trunk, and a feeling of constriction round the lower part of the chest was common, sometimes suggesting the Bornholm disease. The blood often showed a slight neutropenia. Giddiness was an occasional complaint during early convalescence. Labyrinthine disturbances were seen in a few instances, but their aetiology was not clear. Convalescence was often slowed by lethargy and depression, and on the average some eight to ten days elapsed after the onset before a man was approximately fit. Reinfection or recrudescence of the original infection was sometimes seen within a period of a few weeks, but some long range immunity was gained, for many of those affected in one year seemed to be substantially protected during the next. In one A.I.F. hospital a considerable proportion of patients had a relapse or reinfection in periods ranging from a week to three months. No sequels were observed. Diagnosis was not difficult once an epidemic began, but there was the usual tendency to attribute most fevers to a prevalent epidemic. Both malaria and relapsing fever have been confused with sandfly fever on occasion.

EPIDEMIOLOGY

It was not found possible to carry out some researches which had been planned by pathological staffs in 1940 or 1941 in Palestine. However,

certain epidemiological observations were made. There was no doubt concerning the constant relation between the vector and the disease. The siting of a string of semi-permanent military camps in an endemic area provided hundreds of excavations and masses of rough rubble where breeding could take place, and countless places where the adult flies could harbour during the day. Yet, so inconspicuous are these minute hairy flies that most of the people bitten by them had never recognised them. A search in dark sheltered places usually revealed them with their curiously hovering and restricted flight. It was noticeable how certain hospital wards harboured infection, and some surgical wards, for example, once seeded with infected flies produced steady crops of the disease among their patients. On occasion outbreaks of short-term fevers were observed in Palestine and Syria whose identity was in doubt. Whether these were dengue or sandfly fever or some other variant was questioned. The absence of suitable mosquito vectors, especially in Palestine, made dengue unlikely. Further, the failure to find sandflies, except by one experienced in such surveys, was not conclusive, though it is admitted that as a rule plenty of vectors are necessary for the spread of insect-borne diseases. In Mersa Matruh, for example, it was stated that sandfly fever was present but without sandflies. This was surely due to the difficulty in finding the tiny vectors in dark dugouts. The same argument was used on occasion in Tobruk also, and is referred to elsewhere. The argument that symptoms are not "typical" is most insecure in the sandfly-dengue group, where the mutability of symptoms and the occurrence of mild cases with little disturbance other than a slight transitory fever are well recognised.

The later work of Sabin, Philip and Paul, of U.S.A., on sandfly fever showed by transmission experiments on volunteers that only demonstration of immunity and passage of experimental infection can clear up some of the problems of epidemics.

There were apparent inconsistencies in the characters of epidemics of sandfly fever as seen in Palestine and Syria, particularly in the Damascus and Tripoli areas, but these may be explained as epidemic variations, or possibly as evidence of different strains or mutations of the virus. In 1941 a short-term fever occurred in Sarafand in Palestine, in which a rash and glandular enlargement were common, and which resembled both sandfly and dengue fevers. Occasionally symptoms suggesting encephalomyelitis were seen. Without strong reasons it is, however, better not to subdivide classifications of infectious diseases which have similar clinical and epidemiological patterns.

The question of the occurrence of sandfly fever in Australia or New Guinea has been raised. In Australia no *papataci* varieties of the *Phlebotomus* are known, and, though comprehensive entomological surveys of all areas have not been made, there is no proof that sandfly fever exists in Australia. The same holds for New Guinea. It has been stated that sandflies were found in part of the Milne Bay area, and that they were abundant on some beaches between Salamaua and Lae. In the latter areas a short-term fever affected a considerable number of men. However,

no species of *Phlebotomus* which bites man has been found in these areas. It was established that the Salamaua-Lae outbreak was not malaria, and though its nature was not determined, no proved vector of insect-borne disease was discovered. The "sandflies" were found by entomologists to be of the *Culicoides* family, blood-suckers, but not known to transmit disease.

PREVENTION

Preventive measures against sandfly fever were not attempted on any wide scale in the Middle East. The breeding grounds of the sandflies were extensive, and neither material for effective sprays nor the means of applying them were readily available. Even the irritation of sandfly bites did not seem to goad sufferers into attacking the pest seriously. Repellent creams then available were greasy, uncomfortable and ineffective. Even had a good preparation been obtainable in 1940 no repellents were on issue in non-malarial areas, where most of the attacks occurred during that year. Mosquito nets did not adequately exclude sandflies and sandfly nets were not then available. The use of modern repellents and insecticides should alter the whole position of prophylaxis.

2. DENGUE FEVER

There had been extensive experience of dengue fever before the war in civilian communities in Australia. The disease had made its presence felt under three guises, that of the endemic form in northern areas such as Darwin, Thursday Island and Broome, the epidemic form in areas annually visited by the infection as it spread over the southward routes, where it was modified by a degree of protection in the community, and the epidemic form in areas visited only in exceptional years when it spread over communities virtually unprotected. In the first form it may be classed as chiefly a nuisance to newcomers. It has been suggested in some tropical areas that infection in native children may keep the virus active. The second form allows the disease much more scope, but it does not attain the role of a disrupter of a community as it has in areas usually untouched by its epidemic waves. In a mobile population like an army it may be of great importance and can contribute materially to the wastage of men and increase the strain on medical units.

SYMPTOMS

The features of dengue fever are well known to most practitioners with experience in the northern and north-eastern parts of Australia, particularly in the coastal zones. One feature, common to this group, as already pointed out, is not sufficiently recognised, that the clinical picture is variable, and even striking signs and symptoms in one outbreak may be inconspicuous in another. To regard a "saddle-back" temperature graph as an essential, or severe joint pains, or a rash of a particular type, is to confuse diagnosis. Notwithstanding this qualification the broad outlines are characteristic. As dengue fever was seen in the Services it was an illness

of sudden onset, with considerable early malaise and pains in the limbs, quickly producing prostration which was often severe. Restlessness at night, apparently related to pains in the muscles and their tendinous attachments, contrasted with a dull and drowsy state by day. Puffiness and redness of the face were less conspicuous than in sandfly fever. Splenic enlargement was rare, but the lymph glands were often swollen. Congestion and tenderness of the eyes and pain on moving them were common. Disorders of taste also occurred. Nausea and vomiting and also diarrhoea were occasionally evident during the early florid period of illness. Abdominal discomfort was a feature of some epidemics, for instance in many of a series of over 400 cases seen in one of the Borneo operations.

The usual rashes were observed in a considerable proportion of cases. The preliminary rash usually appeared early and was commonly erythematous, and less often morbilliform. More characteristic were the later rashes, which were often, though not necessarily, seen in connection with a secondary rise in temperature. They were usually macular or maculo-papular. Petechiae were not uncommonly seen especially in severer infections, and chiefly on the extremities. Desquamation frequently followed the fading of the rash. Pruritus occurred in a considerable number of patients. The lace-like patterning of normal white skin described between the fading areas of the rash was often well seen. As a rule no palatal eruption was seen, but it has been recorded. Mild congestion of the mouth and throat were usual, but catarrhal symptoms were as a rule absent. Joint swellings were only very occasionally seen. A mild leucopenia was sometimes found, with an associated decrease of the granular white cells in the blood. The temperature was either of the single or double phase type, the latter causing the so-called "saddle-back" chart. The period of fever was not uncommonly three days, but this was often exceeded. Bradycardia was a well marked feature.

Residual aching in the limbs was sometimes troublesome and an aftermath of mental depression and lassitude prolonged the convalescence of some men. No really important sequels were observed. In some epidemics asthenia of both physical and mental types was common and delayed complete recovery. This was possibly most conspicuous in the considerable epidemics of dengue fever which occurred in the Northern Territory in 1941 and 1942, but in these there were other psychological factors, which exaggerated the effect of isolation both from home and from the forward areas.

No substantial evidence was found of the existence of a neurotropic strain of dengue. Affections of the nervous system during attacks of dengue fever have been observed, usually of the nature of encephalitis. The causal relation does not seem to have been positively established, but the occasional involvement of the central nervous system is more probably due to one of the many variants to which the disease is subject than to a well-defined neurotropic strain. In a medical unit receiving prisoners of war after their release in Malaya, two patients were admitted with dengue fever in which there were some of the less usual features, such as palatal

vesicles and temperature of low range but biphasic type. One man was in a state of violent delirium from which he recovered after a drowsy period, and was readmitted in a state of acute mania. The cerebro-spinal fluid was not under increased pressure. The blood showed 14,000 white cells, 85 per cent polymorphs per cubic millimetre. He recovered rapidly with the absence of one abdominal reflex as the only other abnormal sign. In other respects the clinical picture was thought to be that of dengue, with a macular rash, enlarged glands, painful eyes and congested pharynx.

Investigation of a small series of patients with signs of neck stiffness due to dengue showed that in a few an increase of the cerebro-spinal fluid pressure occurred; in a very few it rose to 200 or 300 millimetres of cerebro-spinal fluid. The protein was on occasion also slightly increased; in one instance to 90, and in another to 200 milligrammes *per centum*. In the latter the cells numbered 23 per cubic millimetre, but had fallen a week later to 10. Increase of cells was only an occasional finding, and then the increase was usually slight.

Immunity was usually conferred by an attack, but this was sometimes only partial. In the naval quarters at Townsville in 1944 a number of men were readmitted within a few weeks with a second attack in which the pattern of fever and symptoms was somewhat different from the first attacks. Two categories of illness were recognised in this outbreak, one with high fever, the other practically afebrile. Ross, in observation of dengue fever at Fanning Island, has studied these practically afebrile attacks, which are found also in the experimentally produced disease. By feeding *Aedes aegypti* on a patient in the first day of illness and allowing the mosquitoes to bite a volunteer he produced an almost afebrile attack. This volunteer had a history of two previous attacks, and Ross has suggested that the afebrile type may represent the reaction of a partly immune person.

DIAGNOSIS

The close resemblances between the signs and symptoms of sandfly and dengue fevers are obvious. The difficulty of diagnosis of both is sometimes considerable at the start of an epidemic or in isolated cases, but the careful observation of both diseases by service medical officers has shown that thorough examination and observation of patients will reveal a fairly characteristic picture in each case if individual symptoms are not regarded as criteria. In the Northern Territory at one time heavy maculopapular rashes suggested measles, but the general clinical pattern was of course quite different. No ordinary pathological tests can do more than give some confirmation of the diagnosis. In malarial areas dengue often posed difficult problems of diagnosis. This could be seen in areas such as Milne Bay after the repulse of the Japanese landing. The amount of malaria that was beginning to sweep the area was not realised at first in all quarters, and the difficulties of demonstration of malarial parasites in men taking suppressive drugs helped to confuse the diagnosis. Comparison of diagnostic figures in Milne Bay showed that their accuracy depended largely on the experience and competency of various services to diagnose

malaria. Pathological resources were then slender in Milne Bay, but the special training of numbers of Australian medical officers and technicians in the microscopic demonstration of malarial parasites in thick films was of great assistance.

EPIDEMIOLOGY

The epidemiology of dengue has always been of interest in Australia, and during this war some fresh aspects appeared. The Commonwealth Health Department's publication on dengue fever pointed out that the distribution of the disease depends on the distribution of the mosquito host, climatic conditions and the existence of herd immunity. In Australia it is only in the endemic areas of the north that the virus can develop consistently in the mosquito, since the temperature there does not consistently fall below the critical temperature of 64° F. In Darwin, the endemic area of greatest importance, the incidence of dengue rises from September to March and falls in the dry season from April to August. Dengue was rife among all Services in the Darwin area. At the end of 1939 the number of non-immunes there was estimated at 2,000. The Director-General of Health sent an entomologist there from the School of Public Health and Tropical Medicine in Sydney, and vigorous anti-mosquito work was undertaken. Among the troops there in 1942 the incidence reached 10 per 1,000 per week. This incidence was surpassed when the disease spread along the air routes to the coast, which is its usual method of extension.

At Townsville a rate of 25 per 1,000 per week was reached, in other words 1,300 per 1,000 per year. Here the problem of control was more difficult than in Darwin, where there was unified control, and less admixture of servicemen and servicewomen and civilians. The known carrier in Australia (*Aedes aegypti*), being domestic of habit, and breeding chiefly in careless accumulations of water about habitations, could be effectively controlled with sufficient effort. Experiences in the past have shown how difficult such control is in civil communities. Regular inhabitants acquire immunity and remain careless. Even in service installations good discipline and considerable effort are required to reduce mosquito populations. In 1940 an epidemic of dengue fever affected 80 per cent of the troops in Port Moresby area, military and civil authorities each blaming the other.

The epidemic in Townsville had some interesting features. Spreading via Cloncurry, Longreach and Charters Towers it first reached Townsville in September 1941 as a sporadic outbreak. By November the civil population was heavily attacked, and next month the R.A.A.F.; army units felt the impact fully by February 1942. Cooperation was obtained between civil and service organisations with beneficial results. In Darwin great efforts were made to remove the abundant potential breeding places, and arrangements were made for spraying of planes leaving the local airfields, and for the disposal of rubbish. Thursday Island and the other islands north of Cape York were heavily affected with dengue also. If the Darwin areas in particular could be controlled the chief endemic centres would cease to feed the yearly flow of the disease southward, where it regularly attacks Queensland and the north of New South Wales.

The distribution of *Aedes aegypti* was known to be wide, even to the central part of New South Wales. McCulloch carried out entomological surveys which showed that this mosquito was more widely spread and more resistant to adverse environment than had been thought. Efforts were made in 1942 to suppress mosquito breeding as far as possible, as troop concentrations and movements were increasing on the Australian mainland with the more tense military situation. A regulation was made early in 1943 under the *National Security Act* to enforce notification of dengue fever by all medical practitioners. Information as to the incidence of the disease was regularly furnished by the Chief Health Officer of each State to the military authorities. In Western Australia also there was little doubt that the dengue vector and the disease were seasonally present over wider areas than had been believed. Doubt had been expressed whether it occurred south of Geraldton, but outbreaks of short febrile illness, especially of the house epidemic nature, left little uncertainty about their nature. A survey of Western Australia by army entomologists showed the advisability of mosquito control in Geraldton, which was likely to be a centre of troop movements.

Before the New Guinea campaigns had begun, and for some time after, study of dengue fever in the north of Australia afforded ample opportunity of seeing how a mosquito-borne disease might swiftly flare into a large epidemic. Group Captain Baldwin pointed out that it was possible for half or even three-quarters of a body of men to be attacked with such incredible speed as to arrest military operation for several weeks. Even in some of the island areas where the disease occurred extensively, it was not a pre-existing infection (that is, of "jungle" type, with an animal carrier) but was brought in from other endemic areas by the men themselves.

The Japanese realised also its inroads on manpower, and from intelligence reports it was learned that they claimed to have produced a method of conferring immunity by diluted doses of serum from patients in the florid stages of the disease. No evidence of the use of such a method was found in the islands.

STUDIES ON VECTORS

The question of the insect vector was all-important. Studies of epidemics indicated that there were probably vectors other than *Aedes aegypti* and *albopictus*. The latter was not a prominent vector in most of the areas where Australians served, but in Labuan and Tarakan where considerable dengue fever occurred it was important. In Tarakan a fever of doubtful aetiology was encountered. It was thought to resemble sandfly fever more than dengue fever, chiefly on account of the absence of rash. There were no sandflies and *albopictus* was plentiful; it seems certain that this was dengue fever. During the first New Guinea campaign in 1942-1943 extensive epidemics of a disease believed to be dengue fever occurred, but in areas where no *Aedes aegypti* could be found. Accordingly an investigation was undertaken by the Australian Army Medical Services. A number of species of *Aedes* mosquitoes were collected at Port Moresby, fed on

volunteers in the early stages of dengue fever and flown to Sydney. The species selected were abundant at Moresby and Milne Bay: *A. funereus* Var. *ornatus, similis,* and *vigilax*, and *Mansonia uniformis*. They were allowed to bite healthy volunteers in Sydney who had not been exposed to dengue fever, but these attempts in transmission were unsuccessful. Later, when Lae and Finschhafen were taken, extensive epidemics of a disease confidently diagnosed as dengue fever occurred in these bases and also in the Ramu Valley. *Aedes scutellaris* was observed to be prevalent there, particularly in the localities where dengue occurred. Mosquitoes of this and other suspect species, such as *armigeres,* were grown from larvae, fed on donors selected as suffering from dengue, and flown under high priority to Sydney. This time transmission experiments at the 113th General Hospital, Concord, were successful. Volunteers on whom the mosquitoes were fed contracted illnesses clinically recognised as dengue fever, and by intravenous inoculation of their blood into other volunteers, and further sub-inoculation from the latter, the second and third generations of the infection were produced. The experimentally produced disease was characterised by prodromal headache and backache for several days, a rapid onset, pain in and suffusion of the eyes, redness of the palate, a macular rash on the trunk, and one-phase and two-phase types of temperature. Bradycardia was common. Sub-inoculation was successful on the third or fourth day. Re-inoculation of the original volunteers failed to produce the disease, thereby establishing the presence of immunity. As none of the volunteers had ever been in a dengue zone, the proof was definite that *A. scutellaris* could act as a vector of dengue. This explained the occurrence of dengue over a wide area in New Guinea: it seemed possible that there might even be other vector mosquitoes. This work, carried out under Lieut-Colonel Mackerras, Director of Entomology, illustrated how essential it is to have exact knowledge of all factors concerned in the propagation of insect-borne disease. It is of interest that Ross, whose observations on dengue on Fanning Island have been referred to above, has noted the presence of *A. scutellaris* there.

PREVENTION

Control of *A. scutellaris* was not as simple as of *Aedes aegypti* which has more domestic habits and can be dealt with by abolishing casual water about dwellings. Dengue control being largely a question of mosquito control was dependent on study of the habits of mosquitoes, and these varied considerably in different areas. In settled areas tins were the main breeding places of *scutellaris*; in many localities coconut shells were of the greatest importance, and in the Ramu Valley the axils of banana and taro leaves were favoured by the vectors. As the *Aedes* is a day biter, protective clothing and repellent lotion were also important. In the North-Eastern Area in 1944 it was noticed that proportionately more members of the W.A.A.A.F. had dengue than the men of the R.A.A.F. The suggestion was made that protective clothing should be worn by women, that is slacks and long-sleeved shirts, but control of the breeding of mosquitoes was

considered a much more important factor. In hospitals the use of mosquito nets and spraying of wards were necessary in infested areas. Exact study of the biting habits and flight characteristics of individual mosquito species was important. In the case of *A. scutellaris,* for example, such study showed the hours at which the mosquitoes entered tents or buildings and therefore the most effective hours for spraying. *Scutellaris* bred abundantly at 1,800 feet above sea level, and adults were found at Sattelberg, at 3,200 feet. On the other hand larvae have been found within a few feet of the edge of the sea. Epidemic control was assisted considerably by measures adopted against the adult mosquitoes. Spraying close to the ground near the places where biting was concentrated and denying harbourage to the insects in all possible ways were effective. Broadcast spraying with the potent modern insecticides gave the best promise in the later phases of the island war. It was most important to realise that a heavy vector population in a new area might at first be harmless until the mosquitoes themselves were infected from outside. An army fighting in such areas and based on endemic areas carries these troubles with it. Aircrews can easily introduce infection of fresh areas. Once infected, the *Aedes* can transmit the infection in twelve days, and can do so for the rest of its life of some 280 days. Intelligence concerning the local habits of insect vectors can be of high importance. The study of epidemiology of dengue fever has been of great significance during this war not only for its intrinsic importance, but because it was a small scale model of the much more vital subject of malaria.

3. EPIDEMIC POLYARTHRITIS

During 1941-1942 a febrile illness was observed in the Northern Territory of Australia which was associated with affection of the joints. This was at first thought to be of rheumatic origin. Lieut-Colonel Ingram reported numbers of cases of subacute rheumatism in young soldiers without carditis, and without obvious infective focus. The joints, particularly wrists and knees, were involved in a process which caused pain and crepitus, and which resolved completely.

In the summer of 1942-1943 Halliday and Horan, working in hospitals at Adelaide River and Katherine, noted the prevalence of an acute febrile illness with articular symptoms, and studied over 100 cases. Such epidemics had been reported before, and in 1928 J. R. Nimmo described "an unusual epidemic" at Narrandera, in the south-western area of New South Wales. This took the form of a mild febrile illness with a transient rash, painful swelling of the joints and some tenderness and enlargement of the lymph glands. It was observed in a number of areas in the west of New South Wales during an unusually wet summer. During the previous summer there had been an extension of dengue fever along the inland rivers of this State as far as 32° south, but Nimmo thought this epidemic of 1928 was not dengue, as this disease had not been definitely observed as far south as Narrandera, which is over 34° south. Edwards, however, who saw similar cases, thought they were dengue.

Halliday and Horan have described what appears to be the same disease, and called it "epidemic polyarthritis". Most of the investigations were carried out by Halliday at the 119th A.G.H. at Adelaide River, Northern Territory. A striking feature was the absence of severe constitutional disturbance, and of headache or pain in the eyes. The onset was gradual rather than sudden. Pains in the joints were invariable, and swelling also occurred in the severer forms. Fever was mild and of short duration. The joints of the extremities were most often affected; swelling when present was due either to peri-articular thickening or to effusion or to both. These signs subsided within a week, leaving some degree of stiffness which passed off in two or three weeks' time; occasionally this lasted longer. Tender swellings of the lymph glands occurred. There was occasionally an evanescent maculo-papular rash in the first few days, and in a few instances petechiae were seen; there was never any desquamation. Bradycardia was not observed. Investigations of the blood, urine and all systems failed to reveal any organismal cause. Halliday and Horan did not think this was dengue fever on account of the different clinical picture with its predominantly articular pattern, which did not resemble the dengue fever seen in the area. They noted too that most cases came from areas where dengue was not prevalent and where *Aedes aegypti* was not found. No sequels were observed, though the glandular enlargements cleared slowly.

Towards the end of the epidemic Professor E. Weston Hurst, of the Institute of Medical and Veterinary Science of Adelaide, visited the area, and collected material for bacteriological examination, but inoculation into animals and developing hens' eggs failed to disclose any infective agent.

Many patients suffering from this condition were seen in various parts of the Northern Territory, including men from the Royal Australian Navy, Royal Australian Air Force and the United States Army at Larrimah and Adelaide River. A few cases were seen in September 1942 and possibly earlier; the peak was reached in December and January. There was then some spread of the epidemic towards Western Queensland; probably patients were also seen at Alice Springs. No heavy incidence was observed in circumscribed areas, and there was no evidence of infection by contact, though as high as 14 per cent incidence was found in some units.

In succeeding years outbreaks of an apparently identical condition were described by several observers. In Townsville and Innisfail, on the Atherton Tableland and other parts of Queensland it was recognised. Sibree, in a study of a series, thought it distinct from dengue. Dowling pointed out that outbreaks had occurred in at least three wet seasons in Northern Australia. Goswell observed over fifty patients in an Australian air force station in the Adelaide River-Katherine area. He found the exanthem of a constant type but, while noting the absence of constitutional signs, pointed out a wide variation in severity of the joint affection. Other slight variations in symptoms were observed in different parts of Australia, such as the occurrence of headache as a prominent feature, and slowness in recovery of stiffness of joints. Short in an outbreak in Queensland noted

the prevalence of March flies. The same disease has been recognised also in the South-West Pacific Area, for example in Bougainville.

No association with insect vectors was observed in any area, though it was remarked that culicine mosquitoes were distributed over the areas affected by the disease. While there are obvious similarities between this condition and the dengue-sandfly group of diseases there seems warrant for regarding it as a distinct entity. It can probably be ascribed to an insect vector, but this has not been proved. It seems to be established that dengue fever and a dengue-like disease, equally benign in its general effect, co-existed during the war years in Northern Australia, thus adding another variant to the growing group of short-term fevers.

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CHAPTER 9

TYPHUS FEVER

BEFORE the war considerable interest had been taken in rickettsial diseases. Murine typhus was occasionally seen, mite-borne typhus had been revealed as one of the important endemic diseases of Northern Queensland, and Q fever, a rickettsial infection, though not apparently closely related to the typhus family, had been discovered in Queensland. These diseases had stimulated interest in insect vectors, fleas, mites and ticks. Rather contrary to expectations Q fever, though a feature of the medical conditions in some of the Mediterranean battle areas, was not found among the Australian forces. It is possible that some of the pneumonic illnesses of undetermined type may have been of this variety, but no evidence exists.

MURINE TYPHUS

In 1920 Hone recognised the endemic form of typhus among wheat workers in South Australia. Since then sporadic cases of this type have been encountered, with a few local outbreaks, the largest of which occurred in Toowoomba in Queensland in 1925. This was associated with a plague of mice, but no causal relation was ever established. Immunologically this endemic form is of the murine variety, which is due, as Burnet has said, to "man's accidental intrusion into that almost equilibrated biological system, rickettsia, rat-flea and rat". There is some evidence that smouldering foci may exist in urban areas on or near the coast. The number of endemic cases occurring in Australia yearly fluctuates, but is not inconsiderable. In 1939 there were 210 cases, in 1942 the number fell to 63, but in 1944 rose to 238. During the war murine typhus was not of any special importance in Australia, though cases were recognised in widely different areas, such as the central western coastal areas in Western Australia, where its features have been not unfamiliar, on the Atherton Tableland in North Queensland and in Port Moresby in New Guinea. In a few instances infections seemed to be related to working in partly demolished buildings. No eschar was seen on the skin, and the serum contained agglutinins for the Proteus type *OX* 19. No epidemiological problem of military importance was involved in these sporadic infections, nor was there at any time on any Pacific front a risk of louse-transmitted typhus. The possibility of an outbreak was considered during the Western Desert campaign, owing to the aggregation of large numbers of Italian prisoners of war under conditions of defective hygiene, but fortunately nothing of the kind happened. While the 9th Australian Division was still in Palestine and Egypt at the close of 1942, the potential dangers of epidemic typhus fever were set forth in instructions promulgated by the British Headquarters in Middle East. In these the precautions to be taken in the handling of civilian labour were detailed.

MITE-BORNE TYPHUS

Mite-borne or scrub typhus was, however, a serious problem especially during the earlier phases of the Pacific Island campaigns. This problem did not so much concern the total depredations of the disease on the forces, which were never comparable with those of malaria or dysentery, but rather the severity of the disease itself. The mortality varied under different conditions; the overall death rate was 9 per cent in the Services. Not only did scrub typhus impose an increased burden on medical and nursing resources, but it also was feared by the soldiers themselves more than any other disease. The need for early evacuation to hospital and for long convalescence created further strain on medical arrangements.

Clinical observations during the war began during the first New Guinea campaign. The symptomatology was already familiar to Australian physicians, following the studies of Unwin, Mathew, Heaslip and others in North Queensland, and Gunther in New Guinea. Scrub typhus had been proved to be one entity in a loosely named group of fevers called "coastal fevers" in Queensland, and the disease seen there was believed to be identical with the form known in Malaya and the *tsutsugamushi* fever of Japan.

It was known that mite-borne typhus varied considerably in severity in different localities. This fact had made studies of epidemiology more difficult, though it was realised that the disease had a wider incidence than was apparent. When Australian troops attacked the Japanese advancing over the Owen Stanley Ranges towards Moresby typhus soon appeared among them, and one of the most obvious features of this outbreak was its severity. This was greater than was expected, though it was soon realised that the extraordinarily severe strains of fighting in this difficult country, without proper rest and with monotonous and often insufficient food, would decrease resistance. To this imponderable factor of personal resistance perhaps must be added other biological factors, such as the greater toxicity resulting from passage through human bodies. Age was also most important. In one series the mortality was doubled in men over thirty; certainly the prognosis was more serious in patients over thirty-five. Not only did hardship thin and weaken the men, but they suffered too from dysentery, and later from malaria. During one phase of the Gona-Sanananda action the mortality from typhus rose to 25 per cent in a series of 150 men. In the whole of this 1942-43 phase in New Guinea 9.7 per cent died of 626 men admitted to the 2/9th Australian General Hospital, whereas the overall mortality in New Guinea during this period was below 7 per cent. In Burma and Thailand the men of the 8th Division also were attacked by scrub typhus. Here conditions of malnutrition and intercurrent disease could hardly have been worse; but the severity of the disease does not seem to have been as great on the whole as might have been expected. The question of local factors in determining incidence and severity may be left for later discussion.

The mortality rates for the Pacific areas were as follows:

Year	Total Cases	Total Deaths	Percentage of Deaths to incidence
1942	186	40	21.50
1943	1,870	112	5.98
1944	602	78	12.95
1945	181	27	14.91
Total	2,839	257	9.05

The disparities in these death rates are hard to explain: the high rate in 1942 is probably due in part to the nature of the campaign and also may be a fallacy of a small series.

A statistical analysis was made by Captain H. V. Napier for the period 11.12.43 to 8.12.44 when troops were engaged in a number of areas. This showed the following figures:

	Moresby	Buna Dobadura Oro Bay	Lae Nadzab	Madang	Finsch-hafen	Ramu	Total
Mortality rate per cent	10	8.3	12.1	18.3	6.7	6.1	8.3
Standard deviation	5.5	2.7	4.0	5.0	1.8	1.5	1.0

The total number of cases was 715. The dissected death rates for the first and second halves of 1944 showed a curious disparity, the first being 6.8 per cent (S.D. 1.0 per cent) and the second 17.0 per cent (S.D. 3.8 per cent).

It will be seen that scrub typhus can produce a high mortality rate in restricted series, and in restricted areas, but the consolidated rate for the island campaigns did not exceed 9 per cent of the incidence.

THE CLINICAL PICTURE

The military problems set by the disease were the provision of hospital care for men likely to be seriously ill, and the investigation of the possibilities of its prevention. During the rapid expansion of the 2/9th Australian General Hospital in the upper Moresby area made necessary by the first New Guinea campaign, opportunities were taken to make careful clinical studies of the disease as seen in these areas, and further observations were made later in other combat areas in the South-West Pacific and the Netherlands East Indies, and in the training area in the Atherton Tableland in North Queensland. In February 1943 a medical technical instruction was issued describing the chief characters of the disease, its diagnosis and methods of handling. Though the purely clinical features of mite-borne typhus are discussed at this stage, it must be realised that studies on its epidemiological features were proceeding simultaneously, and that important work on its prevention also began early in 1943. Williams, Sinclair and Jackson in an account of 626 cases studied in the

2/9th Australian General Hospital in 1942-1943 recognised four grades of clinical severity, ambulatory, mild, moderate and fatal. Not many ambulatory infections were observed, though later immunological studies in Australia of groups of men exposed to infection indicated that these may occur rather more frequently than can easily be proved. Despite the severity of the disease in some areas, even here numbers of mild cases were seen in which the characteristic diagnostic features were present. Complications and involvement of special systems were absent, and the illness was over within a few weeks. At the other extreme were the rapidly fatal infections, in which at the end of the second week death appeared imminent, and after the onset of circulatory failure coma was the herald of the end. Among the moderately severe infections were classed those in which recovery was achieved in some six weeks, allowing return to ordinary full military work in three months from the time of onset. To these types must be added another variant which is not uncommon among all kinds of typhus fever, the type which affects the desperately ill patient who contrary to expectation recovers. In few diseases are there seen such striking examples of the return of dangerously ill people from the shadow of death. This phenomenon when it is seen is all the more striking because of the rapid lysis which often terminates the fever in this disease.

A moderately severe course usually opened with a fever of rapid onset with shivering, malaise, headache, a little dry cough and frequency of micturition. The headache was characteristically persistent and severe. Not infrequently the initial diagnosis was malaria or a short-term fever, and until the disease pattern was recognised, the correct diagnosis was often made by failure of the symptoms to respond to anti-malarial treatment. Signs of toxaemia increased, and cough became more severe in the next few days, with constant fever, the tongue was heavily coated and the eyes were suffused. A small "eschar" was found on search in about 60 per cent of cases. Some stiffness of the neck usually appeared, and the mental state showed some deterioration, owing to increasing apathy. A rash was common towards the end of the first week, and superficial adenitis was often apparent. The temperature was usually remittent, rising in peaks to 103° and over. The pulse rate was increased, but usually not in proportion to the temperature. The cerebro-spinal fluid pressure was raised. In the second week of this continued fever cough often produced frothy blood-stained sputum. The eschar showed definite ulceration and the rash faded, and in severe infections a degree of subcutaneous oedema appeared in dependent parts. Few if any signs were found in the chest, though the respiratory rate was increased. The blood pressure fell, the systolic pressure often being below 100 mm. Hg. Apathy increased, and was often associated with an unhappy querulousness, yielding often to delirium and disordered dreams. In most infections of any degree of severity some anxiety was felt at the end of the second week. Nursing was a constant and arduous task, especially if incontinence added to its difficulties. Signs of renal involvement were not unusual, with the appearance of protein and casts in the urine, and a moderate rise to 50 or 60 or more milligrammes of

urea in 100 c.cm. of blood. The diagnosis could now be confirmed by the finding of a raised and rising titre of agglutination for *Proteus OXK*. Signs of involvement of the nervous system often included nerve deafness, and loss of deep reflexes.

During the third week, when the illness was most intense, improvement began in favourable circumstances, sweating increased, and the temperature fell by a rather rapid lysis. Clinical improvement often anticipated the subsidence of fever by a brief period, 12 to 24 hours, and recovery was thereafter usually uninterrupted. Residual weakness was frequently extreme. After a severe attack the wasting and incapacity for exertion were considerable, and for two or three weeks the patient could do little. Glandular enlargement often persisted for some time. Convalescence occupied at least as much time as the total period of hospital illness, and sometimes longer. Comparison of the signs and symptoms of diagnostic importance showed that these varied in incidence and nature in different outbreaks, as might be expected. Thus Williams, Sinclair and Jackson found an eschar in almost 60 per cent of their patients, but Sangster and Kay only in 41 per cent, while in other small series in New Guinea and Australia coming from localised areas the percentage was only 33. Severe headaches were practically invariable. A rash was seen in about two-fifths of cases; in the 2/9th Hospital series the percentage was 65. Fever was constantly high in most instances, sometimes less high in fatal cases: remission was invariable and was sometimes extreme, swings of 7 degrees being sometimes seen. The duration of the fever was usually about three weeks, but sometimes as long as nearly six weeks.

The various anatomical systems showed important and often characteristic signs.

Skin. The eschar was often difficult to find, especially as the patient was unaware of its presence, since it was painless, though the drainage glands were usually tender. It was rounded or oval, some 2 to 3 millimetres across, with a red areola some 3 to 4 millimetres wide. In the centre was a black slough which separated during or after the second week, leaving an ulcer. The areola was highly characteristic as it was not found to persist in other small non-specific lesions. Healing of the eschar was slow and usually not completed for over three weeks, leaving a small, pitted scar. Occasionally multiple eschars were seen. The site was nearly always on the trunk or proximal parts of the limbs, an indication of the larval mite's preference for skin covered by clothing. It also preferred skin folds, though the eschar was sometimes on flat, open surfaces. The rash was maculo-papular in type, usually appearing on the fifth to the eighth day on the front and back of the chest and the front of the abdomen. It was not infrequently spread over face, limbs, palms and soles within two days of its appearance. Probably it was present in more patients than recorded, it sometimes faded quickly, and mildly ill patients might not have been admitted to hospital. Desquamation was not observed.

Lymph glands and Spleen. Enlargement of lymph glands was common, often in parts remote from the eschar: it tended to be persistent. Enlarge-

ment of the spleen was not regarded as a clinical feature of the disease: when present it was probably due to malaria, but as in typhoid fever, a large spleen may not always be felt during life owing to its soft consistency.

Circulatory system. Rapid pulse rate over 120 per minute was usually an ominous sign, especially if associated with falling blood pressure, and a dicrotic quality could often be detected. Alternating pulse was occasionally observed; extra-systoles were unusual except in severe cases. In view of the known occurrence of myocardial cellular infiltration in patients dying of typhus, special attention was directed to the cardiac condition. Soft tick-tack sounds were often noted, and triple rhythm was noted also but no more than in other severe acute fevers. Electro-cardiographic tracings showed no abnormal rhythms. Some delay in intra-cardiac conduction was sometimes observed. Sangster and Kay out of 235 cases noted increase of the *P-R* interval in 20 per cent, exceeding 0.2 second and even reaching 0.3 second. In severely toxic patients a low *T* wave was occasionally seen, and in one instance a low voltage *Q.R.S.* complex. These signs disappeared during convalescence in surviving patients. Tachycardia at rest was sometimes slow to subside, and continued well into convalescence in a few patients who had been severely ill. The systolic blood pressure fell to a variable extent on rare occasions as low as 80 millimetres of mercury. Signs of peripheral circulatory failure were concomitants of severe infections, as shown by cyanosis and patchy pallor, cold extremities, and oedema. No elevation of venous pressure was found in a series of fifteen patients. Peripheral oedema was not at all uncommon in the severely ill: it was usually limited to the ankles and sacrum, but was occasionally more extensive. Peripheral failure of the circulation, as in other severe fevers, was a common terminal event.

Venous thrombosis was an occasional event, affecting large veins like the femoral: in view of the selective action of *rickettsiae* on endothelium it might have been expected more often. Pulmonary infarction occurred clinically in a small number of patients, with the usual signs; it was not necessarily of very serious import, but was found *post mortem* not infrequently. It may be that some of the pulmonary signs were due to multiple small thrombotic lesions in the lungs. A few cerebral accidents, probably thrombotic, were also observed. The blood commonly showed a mild anaemia, but the haemoglobin content seldom fell below 10 grammes per 100 c.cm.: the anaemia was due mostly to malaria. Series of white cell counts revealed very little change in the total numbers. Individual changes were found, but not sufficient or consistent enough to be of diagnostic value. In the 2/9th Hospital series a rise in the lymphocyte count was found to have some significance. This rise occurred typically just before clinical improvement began. A lymphocyte count of say, 5,000 per cubic millimetre was usually a good prognostic sign. Williams, Sinclair and Jackson regarded it as part of the lymphocytic response of the disease, as seen in the adenitis and the round celled infiltration which is a feature of the pathological pattern. They contrasted with this the lack of neutro-

phile response except in the presence of some secondary bacterial invasion. Thus a pneumonic complication of bacterial origin would give rise to a neutrophile leucocytosis which was regarded as an indication for the use of sulphonamides. A low lymphocyte count in typhus appears to resemble a low neutrophile count in bacterial diseases; it is of evil omen. Studies of blood chemistry showed that the protein, calcium and sodium chloride values were usually lowered. The blood protein content was reduced in the more seriously ill patients and reached its lowest level about the end of the second week. McGovern found that the average in 100 cases at this time was 5.3 grammes per 100 millilitres, and the lowest figure recorded 4 grammes. A rise in blood protein content usually coincided with a rise in the blood agglutinin levels. In some severe and fatal infections the rise in protein content did not occur. A fall in serum calcium content took place, too, but did not parallel the protein content. The average of a series of 58 cases was 8.1 milligrammes per 100 millilitres, taking the figure at the time when the calcium was expected to be lowest. Investigation of other infections seemed to show in the small numbers that could be studied in the field that scrub typhus caused a greater reduction of the levels of protein and calcium than other fevers. The sodium chloride level was also found to be lowered about the end of the second week in severe attacks. Its level was little affected by extra salt given by mouth or intravenous injection.

The question of affection of heart and circulation is important owing to the wide interest it aroused: it will be discussed in connection with treatment.

Respiratory system. Respiratory symptoms were almost universal in scrub typhus. Cough occurred early, more frequently than in typhoid fever, and at this stage bronchitic signs were often discovered on examining the chest. By the end of the first week nearly all severely ill patients showed these signs. When serious illness persisted the signs in the chest also persisted, and loss of resonance, diminished breath sounds and crepitations were frequently noted. Small effusions of fluid were sometimes found, also evidence of consolidation. The development of these conditions increased circulatory embarrassment, and about this time increased respiratory rate and cyanosis were often found. Broncho-pneumonia was diagnosed in over 10 per cent with scattered consolidation, blowing breathing and moist accompaniments. Lobar pneumonia was unusual. A complicating pyogenic pneumonia was not common; 3 per cent of the 2/9th Hospital series were thought to be so affected.

Kidneys. No serious renal complications were observed. Albuminuria and cylinduria were seldom seen except in severe infections in which too the level of urea in the blood was sometimes raised. Urobilin was always present in the urine during the febrile period, but no other clinical signs associated with liver disturbance were seen, such as enlargement or jaundice.

An interesting feature pointed out in a series studied on the mainland was the occurrence of diuresis immediately before the lysis of the fever.

This took place coincidentally with the beginnings of clinical improvement, and was an accurate forerunner of the subsidence of the attack.

Gastro-intestinal tract. Appetite was naturally in abeyance, but vomiting was seldom troublesome. A curious symptom present in a few ill patients was dysphagia. Diarrhoea was frequent in the early stages. As dysentery was a common ailment of the troops in many areas, the cause of this was not always apparent, but investigation did not suggest that a true dysentery was present.

Nervous System. Symptoms referable to the nervous system were universally present in all but the mildest infections. It was thought that even in the first few days the mental state of some patients was not normal, being unduly euphoric. Towards the end of the first week the rather peevish apathy which characterised most patients at that stage gave way to depression or to a confusional state. Delusions and hallucinations were common. Seriously ill patients often were stuporose and inert, the chief problem of nursing being the administration of food, but others were constantly restless and trying to get out of bed. Coma was always an ominous sign. Recovery from these disorders was complete once convalescence was established. An increase of cerebro-spinal fluid pressure was commonly associated with headache and neck stiffness, which were relieved by lumbar puncture. The pressure was raised to over 150-160 millimetres in a small proportion, and in few instances cells and protein content were also moderately increased. The chloride content was decreased below 700 milligrammes in more than half a series examined, which included some of the more severe infections. These abnormalities were more commonly found in patients in whom other neurological changes were present.

Affection of the 8th cranial nerve was frequently seen, in about a sixth of the series. It usually took the form of nerve deafness, and rarely tinnitus; it was variable in degree and mostly bilateral. Recovery was practically always complete and rapid during convalescence, though in one instance the deafness was complete and permanent. Reflex changes were very common; both deep and superficial reflexes were temporarily in abeyance during florid illness. Peripheral loss of motor and of sensory function were both observed in a few patients. The latter appeared to be of the nature of a peripheral neuritis affecting cutaneous sensory nerves of the limbs such as the ulnar nerve. Pareses of muscles were more difficult to evaluate, since a number of localised peripheral palsies were seen in troops, especially at the time when the first large series was studied. Whether these were always due to typhus or were due to neuronitis possibly of virus cause is uncertain. Scapulo-humeral and *serratus magnus* paralyses were seen among others: instances of these and other types, such as peroneal were observed among men who had not had typhus. It seems likely that some peripheral palsies in stuporose patients with toneless muscles were due to pressure.

Muscular tremor, sometimes of the Parkinsonian type, was prominent during the illness in a few patients. The condition was apparently of central origin and did not persist. Muscular fibrillation and wasting over

a wide area of the body were observed in convalescence in a few patients. This state was slow in resolving. In several instances vascular accidents occurred in the cerebral and retinal vessels. The former caused hemiparetic signs with some disturbances of higher cerebral function. In one case it is possible that subtertian malaria played a part. Retinal changes following thrombosis were observed in several patients. In two these were bilateral: one patient died, the other recovered with serious loss of both sight and hearing.

PROGNOSIS

The prognosis has already been touched upon. Inanition, exhaustion, and intercurrent infections were undoubtedly potent adverse influences. The speed with which men came under skilled care was most important. It was soon realised that in choosing medical casualties for prompt evacuation men with scrub typhus had high priority. Air evacuation was much preferable to longer and more exhausting methods. Certain other pointers were noticed. Age has been mentioned: 14 per cent of 101 men over thirty died, but only 7 per cent of 323 men under thirty. The early onset of prostration, mental deterioration, or conspicuous symptoms and signs involving any of the important systems of the body were also bad prognostic signs. The incubation period also appeared to be a certain index of the probable severity of an attack if it was known. Usually it was not known. Andrew reported a study of 21 men who contracted scrub typhus in Queensland after bivouacking in a heavily infected area. In all the most severe cases a period of 12 days was found, whereas all those infections of 15 days incubation and over were mild or subclinical. The suggestion was made that the prognosis of typhus arising from certain areas was worse than from others, but this is difficult to substantiate owing to many other factors, such as conditions of combat, nutrition, intercurrent disease and facilities for early adequate treatment. The serological diagnosis of scrub typhus was helpful in a general way, but, as it was not possible earlier than the second week of the fever, reliance was placed rather on the clinical pattern than upon the result of this test.

DIAGNOSIS

It was known that mite-borne typhus was serologically distinct from the other endemic and epidemic forms and that agglutinins appeared in the blood for *B. Proteus OXK* (Kingsbury strain), but not for the other strains of Proteus. The titre of agglutination rose slowly, and seldom reached a level necessary for positive diagnosis before the tenth day. Therefore it was found convenient to carry out the test at the end of the first and second weeks. A further test in the third or fourth week showed the peak level of agglutinins, but if the previous tests had shown a rising tide of agglutination and if the level attained about the fourteenth day was 1 in 120 or higher, a positive result was recorded. The Technical Instruction No. 41 issued by the army medical services laid down a titre of 1 in 80 as supporting evidence, and a titre of 1 in 160 as diagnostic. The

method of using white mice for intraperitoneal incubation of the blood of a suspected subject was also described. This afforded opportunity for the demonstration of *rickettsiae* in these experimental animals, but in field work this was not practicable. The agglutination tests were carried out in a standard way, with the use of a dropping technique and serial dilutions of serum, which had been preheated to 56°C. "O" agglutinins only were assessed for the purposes of the test, the naked eye being used. Jackson found that in tests from 582 cases the maximum level of agglutination was reached about the 19th or 20th day, and a demonstrable rise did not occur till the 8th day. Therefore the 7th day test showed the pre-infection level, and by the 14th a reliable estimate of the post-infection level could be gained. Very high maximum levels were sometimes reached: in one instance a titre of 1 in 50,000 was recorded. Considerable variation in antibody production was observed, but only in a very small number of patients was no rise found. Within its limitations the test was found very reliable; false positives were practically unknown provided a safe upper limit of agglutination was adopted. Study of this test by a number of pathologists failed to reveal any evidence of multiple rickettsial strains as indicated by different types of response in the agglutinin content of the blood serum. Nor could any support be given to the opinions of those who thought that a low titre connoted low resistance and therefore presaged a bad prognosis. A bedside method was devised by Professor H. K. Ward, of the University of Sydney, in which diluted serum was added to concentrated proteus suspension on a clean slide and mixed by rocking. Agglutination was easy to observe with the unaided eye, but it was found that though the upper and lower limits of agglutination titres were simply recognised, the middle zone was difficult to interpret. As a quick method in the field it had some value, though a negative result was inconclusive. J. de Vidas, surveying experience in the R.A.A.F. in New Guinea, found that agglutinins usually disappeared from the blood within two months. He also found that a slide agglutination test in which dried whole blood and a suspension of proteus were used, gave reliable results for specimens with a significant titre. The laboratory method had the usual troubles incidental to agglutination tests, such as the difficulty of obtaining smooth non-motile strains of proteus. P. de Burgh reported observations on the use of a polysaccharide of *Proteus OXK* in diagnosis. This method is based on the presence of a minor antigen in both *Proteus* and the *Rickettsia orientalis* which can be extracted in polysaccharide-like substance. By precipitation and extraction this substance was prepared and added to a suspension of collodion particles; this antigen gave a ring precipitation in a test with the serum of patients suffering from scrub typhus. This method, though not suitable for field work, proved to be accurate and is of immunological interest.

PATHOLOGY

The pathological changes found *post mortem* were fairly constant. A slight to moderate amount of fluid was usually found in the serous sacs. The heart was usually pale and flabby; sub-pericardial or sub-endocardial

petechiae were sometimes found in the ventricular muscle. Microscopically the most striking changes was infiltration by plasma cells, lymphocytes and monocytes, chiefly in the sub-endocardial and peri-vascular tissues, but to some extent also between muscle fibres. This small cell infiltration was also sometimes seen in the intima of some of the larger blood vessels, and in their adventitia. Like changes were observed more or less in most of the organs. In the brain round-cell infiltration was prominent, but perivascular cuffing was unusual. Meningeal infiltration was seen in a few instances, and occasionally thrombosis of small cerebral vessels. Small haemorrhages were sometimes seen in the brain. In general the changes of a meningo-encephalitis could be produced by this disease. The alveoli of the lungs had thickened walls with dilated capillaries; and mononuclear cells were present in the alveolar walls and interstitial tissues and also the lumina. Varying degrees of consolidation were produced, affecting some or all of a lobe. Haemorrhagic infarcts were sometimes present. The spleen was always enlarged, although this might not have been detected during life. It was soft and friable, most of the normal structure being obscured and the usual lymphoid tissue practically absent. The most striking features of the tissue changes in scrub typhus were an intense infiltration of the organs with mononuclear cells of various types and a great proliferation of reticulo-endothelial tissues. Those features which had the greatest bearing on the attitude of the clinician to treatment were the involvement of the heart, the lungs and the nervous system. In the heart there were undoubtedly signs of myocarditis, but during life the changes found in the circulatory system were no different from those found during other severe continued fevers. There was no warrant for supposing, on the strength of the histological picture seen in fatal cases, that typhus was selectively a cause of permanent organic damage of the heart. The changes in the lungs showed that while broncho-pneumonic complications occurred these were seldom of the usual bacterial kind; specific treatment could be expected to be of value only if specific bacterial invasion had occurred. The nervous phenomena indicated the widespread nature of the disease, and supported the belief that extensive involvement of the nervous system usually occurred in the more severe attacks.

These clinical and pathological studies expanded and diffused the knowledge of scrub typhus already existing in Australia.

EPIDEMIOLOGY

Epidemiological knowledge of scrub typhus was built up from observations on outbreaks of the disease, particularly with reference to locality, environmental conditions and distribution of vectors. The use of substances repellent or toxic to mites added an important weapon to research, as well as providing a means of prophylaxis. Transmission of the disease by larval mites was understood, and the identity of the mites was reasonably sure, but exact information was needed of the distribution of infected mites in the country where difficult campaigns were being fought. Heaslip's work had given strong evidence that the larva of *Trombicula deliensis* was

the responsible vector in Queensland, and the natural reservoir of infective *rickettsiae* was in native animals such as bush rats and bandicoots. The geographical distribution of these mites in North Queensland corresponded with that of the disease. This distribution was distinctly patchy. Over a period of two years Heaslip reported over 50 cases of scrub typhus originating in 20 different places, widely separated over two hundred miles of coastal districts in North Queensland. Gunther had also studied the disease in New Guinea and produced proof that it was identical in nature with the mite-borne typhus endemic in tropical areas from Malaya to Japan. In Queensland the position was hardly so well defined, for there it seemed likely that several different infections had been included under the general title of "coastal fever". However, there was no doubt that scrub typhus existed there, and it was not material whether "coastal fever" or "Mossman fever" were terms strictly scientific or not. But it was not possible to transfer epidemiological information direct to New Guinea. It had not been possible to make any wide surveys in the extensive forest and jungle areas of Queensland, and though the nature of the problem was clear in 1942, its solution was not so clear. Some uncertainty was felt whether a vector other than the mite was concerned. The discovery of Q fever by Derrick had aroused interest in Australian ticks as vectors, as it seemed likely that *Ixodes* ticks transmitted the *Rickettsia burneti* from native host to cattle, from which *Boophilus* ticks imbibed the virus and excreted it, thus giving opportunity for human beings to acquire it through scratching or inhalation. Q fever was a possible variant of tick-borne typhus, but even if unrelated its method of transmission aroused some reflection. The typhus problem, too, was complicated by the skin irritation known as "scrub itch". This condition had been recognised for a long time as due to multiple bites of mites, such as occurred in many parts of the world. The use of the term "mokka bites" common in New Guinea did not give any entomological enlightenment, as it might refer to irritable and perhaps infected bites due either to mites or to ticks. However, in 1942 it was not generally considered likely that ticks played any part in endemic typhus transmission in Australia or New Guinea, though, as will be seen, the question was raised later, and the problem of prevention correctly centred round the larval mite. There were, however, peculiar inconsistencies. The existence of scrub itch in a locality bore no relation to the incidence of scrub typhus, as the former might abound in areas where typhus was rare. But it was thought curious that the mite caused no apparent irritation to its native animal hosts, and also that scrub itch occurred only in some 30 per cent of patients with mite typhus. The eschar of the latter was usually single and was devoid of pain or irritation.

It was known that there were between 20 to 30 varieties of trombiculid mite in New Guinea, and it was uncertain whether more than one variety could transmit typhus. Further, the life history of these tiny creatures remained obscure. Even study of the larval mites responsible for irritable skin rashes in certain urban districts of Australia where investigations had been made had not shed light on their life cycle. The wide dispersion of

some varieties of mites and of supposed carriers, such as rats, the painlessness of the bite which causes the eschar, and the observed occurrence of typhus in areas where mites were hard to find were other difficulties to be reconciled in explaining the transmission of scrub typhus. There was no likelihood of an epidemic of mite typhus in New Guinea, but it was important to try to control a disease with so high a morbidity. The most fruitful methods appeared to be recognition of heavily infested areas, measures taken to reduce exposures to bites and the discovery of an efficient mite repellent.

At the end of 1942 some advance had been made in these aims. In the study of localities several methods of approach were possible—comparison of the topography of the areas where infection occurred, and the density of infection therein, observation of vectors in relation to outbreaks of the disease, and of animals which might be possible reservoirs.

The need for a suitable area on the Australian mainland in which troops from the islands could be trained and rested led to the selection of the Atherton Tableland in North Queensland. Though this was admirable in point of climate and location, and offered country well adapted to training in jungle warfare, it contained foci of infection by scrub typhus. The number, location and density of these areas were not known, since before the war very few people had moved about this heavily timbered country and made such intimate contacts with it as troops would under training. The possible hazard of typhus on the Atherton Tableland was realised from the beginning, but with the concentration of several divisions there it became evident that close local study of the epidemiology was essential. Thus the epidemiological experience gained during the first and second campaigns in New Guinea and during the training periods in Australia produced valuable information. The patchy distribution of scrub typhus was illustrated in all areas. Further, the foci of disease were sometimes extraordinarily limited. For example, early in 1943 it was observed that of a group of cases occurring at Wau practically all arose on the west side of the airfield and within half a mile of it. By comparison troops working in the jungle were scarcely affected. One company had 15 per cent of its men affected within a little over two weeks of occupying an area by the side of a road where they were working. Numbers of such happenings could be cited. One which attracted some notice was an outbreak which occurred in the 2/31st Battalion training in the Edmonton area. This series, though small, was marked by its severity, and drew attention to the need for taking precautions in the northern parts of Australia.

The need for caution in forming generalisations about the relative dangers of different types of country was illustrated in three outbreaks described by Cook. The first occurred in heavily timbered country in the cool elevation of the Atherton Tableland. Scrub itch, due to *Trombicula hirsti,* was troublesome here, particularly in one divisional area. A sudden outbreak of 45 cases of typhus in 4 weeks affected only platoons of companies patrolling one delimited locality. The second occurred near Palm Beach, north of Cairns, 28 out of 37 men affected in a brigade group

belonging to those companies of one battalion which had camped in one particular spot. The third instance was near Dumpu in the Ramu Valley, near the northern coast of New Guinea. Units camped near streams closely fringed by jungle were attacked by typhus, others in kunai grass or in the foothills except in certain localities escaped. These are good examples of the intensity of infection within limited foci, though it should be pointed out that the danger of such foci waxed and waned. Cook thought that an important common factor was the presence of streams emerging from close vegetation, such as strips of jungle, and suggested that carrier animals and insect vectors made contact in these areas. In view of some inconsistencies in the epidemiology he further suggested that alternative vectors might be worth considering, such as a larval ixodid tick. However, such suggestions did not affect the position of larval *trombiculid* mites as the vectors of this distinctive variety of typhus.

The generalisations relating to the types of country were also fallacious, as later work showed. Likewise, observations of scrub itch were illusory, as there was no essential connection between this and scrub typhus. Much of the information on which beliefs were based before the war, was based on the incidence of scrub itch, and had a popular rather than a scientific background. Mites were supposed to abound in rotting vegetation, particularly in dense rain forests. R. N. McCulloch from investigations on the Atherton Tableland concluded that these generalisations were incorrect: mites were rarely found either in the extremes of dense scrub or cleared grass country, or in decaying leaves or timber. More typically their habitat was in narrow belts along the edge of scrub, or clearings in the scrub with little or no grass, or in the shade of trees where grass was sparse. Though it was thought that mites could be brushed off bushes by the clothing of passers by, they were found chiefly to reside in the soil and rarely to climb higher than a few inches from the ground. Mites were proved to reach the trunk by travelling up from the feet. The contrast between the irritation caused by the mites responsible for scrub itch and the completely unaffected skin of the animals which acted as their normal hosts was striking. This was probably an indication that man is not a natural host for the mite.

Mites were collected in various areas and it was found that many unnamed species existed. Womersley and Heaslip previously described twenty-four species in New Guinea alone and these have been added to considerably. This work proved that a light population of mites might exist in an area known to be bad for typhus, but in some such areas mites were recognised that were proved later to be vectors, such as *T. fletcheri* and *T. walchi.* Some of the apparent inconsistencies could thus be explained. Further study showed that the habitat of a given species in Australia was often different in New Guinea. In most of the surveyed country in New Guinea no forecast could be made as to where mites would probably be most numerous. In New Guinea McCulloch found some species only in grass, others in both grass and jungle, and noted no clearly marked belts along the edges of the scrub. By 1943 much more

was known of the factors governing the incidence of scrub itch and of typhus, but little help could be gained from this knowledge in selecting camp sites. Trained men could detect heavy mite concentrations in a new locality, but only in selecting settled areas would this be of value; it was not practicable with a fighting force on the move. Cutting and burning kunai grass round tents or huts reduced the number of mites, but never abolished them, even for a short time. There was little risk to men marching through mite-infested country, but if the men sat, lay down or stood still, the mites were able to establish themselves on their new hosts. There was not much opportunity for work on the relation between mite-borne typhus and animals, birds and reptiles. Heaslip in Queensland and others during the war in New Guinea had found evidence of the native mammals acting as carriers. Southcott also made some observations on birds, since the distribution of *tsutsugamushi* fever through the eastern tropical zones is consistent with bird migration. Only very limited work was possible, but one bird, the pied currawong (*Streptera graculina*) was found to have a high titre of agglutination to *Proteus OXK*. Larval trombiculid mites have been found on birds both in North Queensland and New Guinea. They also infest snakes and lizards, but no opportunities offered for testing the blood of reptiles for agglutinins. One curious observation was reported in 1945 by the A.D.M.S. of the 3rd Division at Torokina that mites had been observed to drop from mosquitoes on to the skin. Even if confirmed this could not lessen the importance of contact with the earth, the natural habitat of *trombiculae,* in the chain of infection.

The species of *Trombiculae* were studied both as to their habits and their capacity to carry typhus. Though most of the eschars were found in the vicinity of the trunk rather than on the distal parts of the limbs, some varieties such as *Schöngastia* habitually bit around the ankles. The capacity of mites to detect new stationary objects introduced into their environment was hard to explain, especially as such local curiosity was only transitory. Most of the identification of species was done by Womersley in Adelaide; he considered that type *walchi* and type *fletcheri* were included in the species *T. deliensis* and *T. akamushi.* They were found in nearly all areas in New Guinea and were established as vectors by the United States Typhus Commission. *Schöngastia* was a common cause of itch in New Guinea, inhabiting jungle and kunai grass.

The work of the American Typhus Research Commission established the identity of scrub typhus in New Guinea with the *tsutsugamushi* fever found elsewhere. The *Rickettsia orientalis* was isolated in a number of strains from ground-up mites, the material being injected into experimental animals. Identification was made by local injection of the anterior chamber of the eye of rabbits. In this way similarity was demonstrated to the strains known elsewhere in the world. Identical mites have been shown to inhabit limited ground areas and to prefer certain body sites in animals, but no means of proving beforehand the capacity of mites in a given area to produce typhus has been found. *Rattus concolor* was proved to act as a carrier.

Work on the *Rickettsia orientalis* was also pursued in Australia. Fielding described a modification of Breinl's method of staining *Rickettsia*. J. L. O'Connor in investigating methods of assessing the potency of suspensions of *Rickettsia,* showed that the haemagglutination phenomenon described by Hirst in influenza virus was also demonstrable in the *Rickettsia orientalis.*

PREVENTIVE MEASURES

While these observations were being made intensive work was carried out on repellents. At the end of 1942 favourable reports were received from U.S.A. on the value of dimethyl phthalate; it was found that when applied to clothing it gave five days' protection under field conditions. This substance had just been selected as a mosquito repellent for use by Australian troops, and contemporaneous work had been done in Australia on its repellent properties. Field research was carried out by a mobile entomological section under McCulloch, and dimethyl and dibutyl phthalate were tested, first in areas in Australia where harmless mites abounded, and later in areas where scrub typhus was endemic, including Queensland, New Guinea and Borneo. Volunteers tested the behaviour of mites in thickly infested areas wearing clothing treated and untreated with repellent. In typhus areas men were selected who had had scrub typhus six months before, and were presumably relatively immune. It was at once apparent that dimethyl phthalate gave remarkable protection against mites: indeed apparent inconsistencies in early results were found to be due to traces of the repellent persisting in the clothing after washing. Treated bands round the limbs were less effective than complete treatment of the clothes. One millilitre per square foot of shirt and trousers, and 1.25 per square foot for socks protected men sitting or lying among mites for at least two days. Rubbing the drug lightly into the material was sufficient to impregnate it effectively. Trial of dibutyl phthalate showed that this was superior to the dimethyl preparation, particularly in its power to withstand washing of clothes, though the latter was more rapid in action at first. Even after being soaked and agitated vigorously in cold water twice in five minutes, treated clothing continued to give protection for eight days. As dimethyl phthalate was then on issue as a mosquito repellent and supplies might be insufficient for a dual purpose, the dibutyl phthalate was preferred. Further, the troops feared malaria much less than typhus, and it was thought that issues of dimethyl phthalate designed for anti-malarial use might be extravagantly used for scrub typhus. As malaria was the much greater military risk this might have been distinctly detrimental to the forces. In 1943 methanol was difficult to obtain in Australia, but there was no shortage of butanol, and therefore adequate supplies of dibutyl phthalate were more likely to be maintained.

In 1943 DDT was on experimental trial, and this substance was assayed as a mite repellent at Dobadura, which was known to be infested with mites and a centre for scrub typhus. Two Australian hospitals were then setting up in a kunai flat ringed by jungle. Volunteers from one of these units offered to perform ordinary duties, clearing grass and scrub from

the area and, in addition, deliberately exposed themselves to mites by sitting or lying about for defined periods. The results of these field tests showed that DDT was inferior to both dimethyl and dibutyl phthalate, while the last mentioned was much superior to the other test substances, particularly in its resistance to washing of impregnated clothing. These experiments were continued only long enough to yield trustworthy results, owing to the risks involved. Methods were then evolved for testing the toxicity to mites of cloth treated with the test substances. The investigators collected mites for these tests by standing still till mites began to run over their boots, when they lifted them with a camel hair brush on to the test cloth. Where mites were abundant a sufficient number would soon collect on any inert object placed on the ground. Mites have surprising mobility for such tiny creatures, some species covering an inch in three or four seconds. Their "stopping time" was observed on treated cloth, and thus a standard could be applied. "Mite watching squads" of men wearing treated clothing were provided by A.A.M.C. units; they worked either with magnifying spectacles, or unaided eyesight. Mechanical means were also used to confine the mites within treated cloth, counts of those stopped being made after a selected interval. The species of the mites was determined by subsequent examination. Many of these tests were carried out at Atherton. Care was taken to control the longevity and activity of mites under varying conditions of climate and temperature. Cloth tests enabled further observations to be made on methods of washing. It was found that little adverse effect was caused by any method of washing or laundering, and as a practical outcome it was established that treatment of clothing with one ounce of dibutyl phthalate per set was sufficient to retain the power of protection for at least a fortnight as breakdown occurred only between the tenth and sixteenth wash. Exigencies of military operations prevented complete tests from being made on some aspects of the repellent powers of various other drugs under trial. Some variation was found in the reaction of different species of mites to repellents. Actually dimethyl and dibutyl phthalate were killing agents rather than simple repellents. "Staway" and "612", American mosquito repellents, were tested at the request of Major Ahern of the U.S. forces; both gave protection against mites, but this did not survive washing of fabric.

As a result of this field work a standard method was worked out by which each soldier treated his own clothing by rubbing in repellent by hand. Official instructions were circulated, and each formation and unit was responsible for seeing that they were carried out. The method was simple. The finger tips were dipped in the fluid, and the hands thus smeared rubbed it evenly into each part of each garment. One ounce of fluid allowed about 70 "smears", which would impregnate the clothing sufficiently to withstand 7 washings in cold soapy water or 3 boilings. A parade lasting fifteen minutes a fortnight was found adequate if properly supervised, to supply protection to each man. More elaborate methods were tried but discarded, and, owing to the local conditions in combat areas, bulk treatment of clothing was not found practicable, nor so satis-

factory as individual application. Blankets were treated in field laundries or in the units, by dipping in a 5 per cent emulsion of dibutyl phthalate. One dipping was effective for three months if the blankets were not laundered within that period.

Field experiences as well as copious experiment proved that the phthalates were not irritating to the body surface with the exception of the scrotal skin and the eyes and then only in concentrated form. Dibutyl phthalate after prolonged trial proved not only effective but harmless provided that the undiluted substance itself was kept away from contact with the eye.

Wading in streams was thought at first to lower the concentration of repellent in socks, as for instance in the Ramu Valley where it was often necessary for men to wade knee deep. Investigation showed that patchy application of the repellent was rather responsible; in any case re-treatment of socks each week with a little dimethyl phthalate prevented mites from biting. Blankets were treated also as soon as supplies were sufficient, and in the latter part of 1944 this precaution was generally applied. The blankets were either treated by hand, with 1½ ounces of fluid for each, or dipped in soap emulsions of the fluid at army laundries. From November 1943 the method of individual protection was coming into general use in the field, and thus began a new phase in the epidemiology and prevention of scrub typhus.

Attempts were made in various areas to disinfect localities known to be densely populated with trombiculid larvae. Sulphur, recommended before the war, was not found to be very effective. DDT was also ineffective. In Queensland in October 1944 dinitro-ortho-cresol was tried in a watery spray. The mites could be thinned out but not abolished. Tidying the areas of surplus vegetation, as previously mentioned, was useful in reducing mite populations for a time. Curiously, even the inhabitation of an infected area, though it might produce a wave of scrub itch and typhus, would be followed after some weeks by a decline in these manifestations of mite activity. This did not hold for all heavily infected areas: at Dobadura, for example, a well known stronghold of mites, recurrences of infection occurred, owing apparently to the springing up of freshly introduced mite generations.

Work was also carried out by Lewthwaite, O'Connor and Williams on the production of a prophylactic vaccine from egg cultures of *rickettsiae*. It was hoped that the yolk-sac method might yield organisms of greater antigenetic capacity. Had this method proved fruitful, it might perhaps have supplemented the huge British project of large scale vaccine production by the cotton-rat-lung method. By the latter great quantities of vaccine were prepared: its protective capacity was doubtful, but the end of the war came before the clinical value of this could be assessed. Unfortunately the Australian experiment failed, as satisfactory active immunisation was not produced in animals with the egg vaccine, and satisfactory suspension of *rickettsiae* suitable for immunological work could not be made. Yet another of the many tragedies occurred in connection with research on typhus fever when Miss Dora Lush, a brilliant worker in the Walter and

Eliza Hall Institute in Melbourne, contracted a fatal attack of scrub typhus in the course of her work.

The epidemiological studies so far recounted left many aspects of mite-borne typhus without adequate exploration, but much was done to bring the disease under control. It should be observed that in this infectious disease as in many others constant surveillance and careful organisation are constantly necessary to prevent outbreaks. Quite apart from the occurrence of mite-borne typhus, some useful applications of the knowledge gained of mites, their habits and control may be made to problems of civil life. The "grass itch" troublesome in some suburban areas of Sydney, "ti-tree itch" of South Australia, "black soil itch" of Queensland, and "scrub itch" of Queensland and New Guinea are all due to mites. Gunther has pointed out too that there is a danger of typhus in overgrown and deserted plantations.

THE RESULTS OF PROPHYLAXIS

It was of course important to determine what would be the effects of the use of an effective repellent in reducing the incidence of mite-borne typhus. The figures are of interest for the forces in New Guinea from the end of 1943 onwards. Twelve weekly periods showed the following numbers of cases of scrub typhus reported:

Period ended	Cases reported
31 Dec 1943	859 (peak incidence)
24 Mar 1944	402
16 Jun 1944	102
8 Sep 1944	56
1 Dec 1944	13
23 Feb 1945	21

A proportion of this decline was due perhaps to changes in the strength and distribution of the Australian forces, but in the main reductions of strength affected areas where scrub typhus was very rare. At the same time the incidence of scrub itch in the troops was markedly reduced. This practical proof of the lethal effect of dibutyl phthalate on mites also helped considerably in establishing faith in the method among the soldiers, always an aid even to the best of discipline.

In order to assess accurately the part played by mite-repelling methods in the regional incidence of a disease so irregular in its distribution as scrub typhus, it is necessary to examine military movements in relation to the incidence of typhus, and in addition such local outbreaks as occurred in the later years of the war. The former study concerns more the operational history, where it will be considered in greater detail. Here it is sufficient to say that analysis shows that a low typhus rate was in general found in those formations whose organisation for instruction of troops and distribution of anti-mite fluid was most efficient, and that in proportion as such organisations improved case rates fell. Such comparisons can of

course only be made between formations carrying out similar military tasks in country known to have foci of infection.

Further study of local outbreaks shed light on other features of scrub typhus, such as its incubation period and the importance of correct technique in the use of the mite repellent. Southcott analysed an outbreak which occurred at Bramston Beach in Queensland following a large scale amphibious exercise. Over seventy cases were recorded in this series. Data obtained by Southcott and Andrew established the incubation period for mite-borne typhus at twelve days, which agrees with the figure obtained by Cook at Palm Beach near Cairns. At Bramston Beach 29 out of 34 carefully studied patients were almost certainly infected within a single day, and the incubation period of these fell between 11 and 18 days, with a calculated mean of 13.06 days and a standard deviation of 1.89 days.

In this exercise 3,000 troops were in the vicinity of the beach for 24 to 36 hours: they had previously been in areas where no typhus had been encountered, and their movements during the period of the exercise were known. Enquiry showed that at least three areas were infected, particularly those in outcrops of vegetation near the beach. Thirty of the thirty-four men had used mite repellent, but in most instances an incorrect method was used, such as application with a fly spray. Despite this and faulty supervision it appeared that some protection was afforded. Most of the affected men had eschars in the axillary or inguinal folds, illustrating the need for special protection in these regions: Williams and his colleagues had already found that they were frequent sites of eschars. Other examples may be quoted of outbreaks connected with failure to use the protection given by dibutyl phthalate.

In June and July 1944 increased numbers of attacks were noted along the coast of New Guinea north-west of Alexishafen. One brigade was concerned, and most of the cases came from two battalions. All the men had been in the neighbourhood of one area at the probable time of infection. Investigation showed that anti-mite fluid was available but that its distribution and application were defective until the occurrence of cases of typhus gave point to the need for stricter organisation and supervision, after which the incidence rapidly diminished.

An outbreak also occurred in the Aitape-Wewak sector along the north-western coast of New Guinea. During the second quarter of 1945 sixty-seven cases were reported compared with seventeen from other forward Pacific areas. Investigation showed in part at least that this rise in incidence was related to a failure to follow instructions accurately. Before this the same force had penetrated areas known by American experience to comprise endemic foci, and had not then had men affected.

Bat Island afforded another example of the value of wearing protected clothing. In May 1944 this uninhabited coral atoll, north of Madang, was abandoned to its animal occupants after twenty-nine men out of forty-seven had contracted typhus within less than two months, with five deaths. Four men who slept in hammocks in a hut on the beach were not infected. Two different research parties later visited the island, several of the U.S.A.

Typhus Research Commission, and a R.A.A.F. research unit. Both these parties were engaged in recovering strains of *Rickettsia orientalis* from mites of the *Trombicula deliensis* species on the local rats. Protected clothing was worn and tent floors were sterilised with creosote. In no instance did infection occur.

Experiences in Borneo during and after the landings there reinforced these lessons. Tarakan and British North Borneo were apparently free of infection and there no cases occurred. At Balikpapan over twenty cases were notified, most of the infections being mild. Here again the affected men came chiefly from one brigade and were infected during one period, July 1945. The infested areas were in neglected plantations. The cessation of hostilities put an end to further research here, but it was interesting that investigations up to that point had discovered very few mites.

TREATMENT

Concerning the treatment of mite-borne typhus, there is nothing specific to write, but a great deal of value to do. There are also a number of things not to do. The importance of speedy evacuation of patients suffering from suspected typhus to medical units where good nursing conditions prevail was early emphasised. The swiftness with which severe typhus may prostrate men is often dramatic. It has been well said that the man seriously ill with typhus fever is as ill at the end of the first week as most men severely ill with typhoid fever at the end of the second week or later. The bodily affairs of a man with severe typhus should be confined to the most automatic acts of living; skill and devotion can regulate this, and there is no doubt that the unremitting personal attention of skilled nurses is here of the highest value. Conscientious and well-trained male orderlies undoubtedly produced some of their best medical work in this disease, but experienced nurses are really needed for the worst cases. On occasion extra nurses have been flown to areas where the demands of typhus were heavy. Sedation was essential for many of the patients with disordered mental states. The respiratory complications produced a great deal of controversy. The occurrence of pneumonic consolidations suggested the use of sulphonamides. Pathological and radiological evidence indicated that bronchopneumonia was common, that both infarcts and lobar consolidation occurred, but the latter was not often due to secondary bacterial infection. The question was raised whether the exhibition of a sulphonamide drug was advisable for the pulmonary condition, and whether it might even do harm unless clearly indicated by the co-existence of a specific bacterial infection. The official position about this was made clear in a technical instruction. This pointed out that extensive trials with sulphamerazine (which was the drug of choice, because it was made in Australia) had shown that its use had not lowered the death rate from scrub typhus. There was no evidence that this or any other sulphonamide drug exerted any influence upon *rickettsiae* as a class. Therefore a direction was given that sulphonamides were not to be given to patients with typhus except for bacterial complications due to organisms likely to be combated by these

drugs. The existence of a lobar consolidation with muco-purulent sputum would justify their use, but the early pulmonary congestive changes which are so well known a part of the picture of typhus fever would not. The usual dosage was advised if the drug was used, and the usual precautions to avoid dehydration and to maintain a positive fluid balance were enjoined. It was also advised that the urine be kept alkaline, though it might perhaps be thought unnecessary to follow this direction rigidly.

Another question which was raised early was that of coincident antimalarial treatment. Many, in fact, perhaps most patients received antimalarial drugs in the early stages when diagnosis was in doubt. But even when the diagnosis was beyond question, it was thought by some physicians that it would be wise to preclude the possibility of an attack of malaria during the illness. Was suppressive treatment to continue? And in 1942 when quinine was still being used as a suppressive, did it have any influence on producing the deafness so often seen? The answer to the latter question was emphatically in the negative. With regard to suppression, there was no general rule, but it was usually discontinued for patients with established typhus. In practice malarial paroxysms did not occur at the height of the fever, though sometimes during convalescence. Indeed in a disease with so profound a reactive effect on the reticulo-endothelial system it would seem unlikely that a patient in the middle of typhus would have a malarial attack. Reports were published stating that atebrin and plasmoquine had a beneficial therapeutic effect in typhus. No evidence supporting this statement could be produced from Australian experience.

Both controversy and difficulty arose over the circulatory phenomena in typhus. On the one hand the disease was known to produce in its severest manifestations cellular infiltrations in the substance of the heart. On the other hand substantial falls in blood pressure occurred, and the concentrations of protein, calcium and sodium chloride in the blood were lowered. Too much was made of these. The first finding was after all based on post-mortem investigation, and similar damage occurs in other severe febrile diseases. There was, however, no evidence that degenerative sequels followed in the heart. Electrocardiographic evidence of damage was so slender as to be negligible. The other circulatory phenomena suggested the possibility of therapeutic action. Attempts were made to restore the lowered content of calcium and sodium chloride by intravenous infusions, and to provide additional protein by injection of serum, either convalescent or pooled serum or plasma. Little evidence could be adduced of the value of such procedures. Some physicians believed that small transfusions, given with cautious deliberation, did good. Too much zeal in this direction did no good, and may on occasion have done harm. The difference between a healthy but ensanguined man whose depleted circulation called for parenteral administration of fluid and a sufferer from a highly toxic disease with known predilection for vascular affection could hardly be greater. Great care was enjoined in the treatment of severely ill patients. Even slow drip transfusions may carry risk. All physicians could quote their surprising recoveries: so can all with experi-

ence of typhus. The middle way between undue zeal and undue conservatism is probably right. The best guide is an understanding of the curious pathological features of rickettsial infections.

Attempts were also made to raise the lowered salt levels in the blood by increasing the intake of salt. No definite results could be proved. The preservation of a positive fluid balance by avoidance of undue fluid loss was probably more important.

A definite risk incurred in the care of a patient with scrub typhus was the production of a circulatory and particularly of a cardiac neurosis. It is curious that this has been observed all over the world, no doubt because of the striking circulatory phenomena and the known histological changes seen in fatal cases. Where undue caution has been observed in regulating the patient's activities in the early days of convalescence, for example, where graduated exercise after severe illness has been apportioned too meticulously, the result has been to produce some variant of the effort syndrome. At the same time the length of convalescence must sometimes be considerable, and will depend as much upon the grade of the patient's illness as upon its duration. There has been no reason to doubt the capacity of an average healthy man or woman to make complete recovery after typhus fever. If the patient is allowed and encouraged to find his own level within the limits of ordinary discretion, there is no reason why he should suffer any circulatory disability, least of all one which may easily be iatrogenic in origin.

The nervous complications of typhus likewise may be over emphasised. Where motor weakness is a conspicuous local or general feature a correct form of occupational therapy is early advisable. Too much diversional treatment and non-purposive movements may only do harm. Drugs have not been found of special value. In occasional instances of muscular weakness prostigmin has been found to be of temporary value. Thiamin has been tried for localised palsies or myasthenic states, without convincing results. Para-aminobenzoic acid has been found of value experimentally, and favourable reports have been made of its use in severe typhus, especially in spotted fever and the epidemic variety. Good results are also recorded from its use in scrub typhus. High dosage was employed so as to maintain high blood levels, up to 30 to 60 milligrammes per 100 millilitres. Australian experiences are limited; it was thought that some benefit might have accrued to the patients to whom it was given, but no parallel series were studied.

TICK-BORNE TYPHUS

Before leaving the subject of epidemiology the work done on tick-borne typhus should be described. Rickettsial disease has been of great importance during this war, as it has in every war, and all knowledge of its nature and transmission is of value. The possibility that tick typhus might be the cause of a relatively mild short-term fever was raised during the siege of Tobruk. This is described in greater detail in Volume II. The

serological investigations of Major G. V. Rudd at the 2/4th A.G.H. failed to give any convincing proof of its existence there. Andrew, Bonnin and Williams described a series of twelve patients suffering from tick typhus all treated in Australian military hospitals on the Atherton Tableland. The importance of ticks as vectors of Q fever and possibly of members of the general groups of fevers known as "coastal" or "Mossman" fevers has been pointed out above. Tick-borne typhus had not been previously described in Australia, though widely distributed through the world. The 2,000 feet high tableland where these infections were recognised is clothed by light timber interspersed with belts of densely growing hardwood forests with thick undergrowth. There is a thick population of native marsupials and rodents which are infested with ectoparasites, mites and ticks. The housing and training of large bodies of troops have thrown into relief instances of disease that otherwise might pass unnoticed among the small bands of timber workers who alone have moved about these areas in the past. The general clinical features of the disease were similar to those of mild mite typhus. The onset was rapid, malaise and headache were intense, an eschar was usually found, the regional glands were enlarged and slightly tender. Other glands were often painlessly enlarged. Continuous or remittent fever yielded to lysis after a brief illness. The febrile period averaged a little over a week. A maculo-papular rash occurred in almost every instance. Mildness was a conspicuous feature of the illness. *Rickettsiae* were demonstrated in the blood of two patients by animal inoculation. White mice were used for these experiments specially prepared by being kept on a diet deficient in vitamins. Inclusion bodies resembling *R. Mooseri* were found in the mice in serous exudates, which when inoculated into the peritoneal cavity of guinea pigs caused fever and scrotal reaction. Intra-cellular but not intra-nuclear *rickettsiae* were found in the tunical exudates. Further work on these strains was carried out at the Walter and Eliza Hall Institute in Melbourne. In the differential diagnosis the occurrence of adenopathy and an eschar help to distinguish the condition from murine typhus, while the consistent mildness of the attacks and freedom from complications mark them out from scrub typhus. No joint involvement as in epidemic polyarthritis was seen. One patient in the series gave a history of having had a tick removed from his back ten days before the onset. Agglutination tests on the serum were made. The Weil Felix test as carried out in these hospitals were considered to be diagnostic only if the titre reached 1/320, or if it rose from 1/160 during the course of an illness. In 274 tests scrub typhus was found consistently to produce a higher titre with *Proteus OXK,* and murine typhus with *OX*19. Agglutination with *OX*2 in these forms of typhus was unusual. The patients with tick typhus all showed a Weil Felix reaction; a titre of 1/160 or higher was found for *OX*2 in every case, and in 9 cases a titre of 1/320 or higher for *OX*19. The most probable insect vector was the *Ixodes holocyclus.* This tick is one of four man-biting ticks found by army entomologists in the area. It is stronger in its preferences for the human host and is the only one which has been found on the troops.



(Australian War Memorial)

Wounded soldier on Tarakan receiving penicillin by drip apparatus.



(A. O. Watson)

Patient awaiting transport—New Guinea.



(Australian War Memorial)

Operation in Main Dressing Station 2/4th Field Ambulance at Soputa.

Funder and Jackson made a study of the *rickettsia* isolated, comparing it with that of murine typhus by animal inoculation and culture experiments. Different features were observed in the behaviour of these strains from that observed in murine strains. Partial immunity was conferred by them for murine strains. Tests of the serum of the patients gave specific complement fixation with an antigen prepared from one of the strains, and it was established that serologically the tick and flea strains were distinct.

Material was also examined by Major Harry Plotz of the U.S.A. Typhus Commission and his colleagues in Washington. They agreed that the Queensland strains were not serologically related to the agents of epidemic or murine typhus or to cognate rickettsial infections. They produced different pathological changes in animals to those caused by scrub typhus, and did not confer immunity to the *R. orientalis*. Certain features of intranuclear growth of these strains resembled those of the agents of the spotted fever group. These and other immunological considerations suggested that the North Queensland tick was caused by a hitherto undescribed *Rickettsia*.

Andrew and his associates excluded from their series any but cases they considered solidly proved, but it is probable that mild varieties of tick typhus are more common in North Queensland than hitherto suspected. Southcott described an undoubted case in which the infection arose at some point on the Queensland coast near Trinity Beach. Brody also described a case in a woman aged 50 years, arising in North Queensland. G. E. W. Streeten and others have since described three cases from South Queensland. Fenner carried out an investigation on mammalian hosts. Ectoparasites were collected from kangaroo rats, opossums and bandicoots, and the animals were bled. Ground-up ticks were used to inoculate guinea-pigs. By complement fixation methods, with the use of an antigen prepared from one of the Atherton rickettsial strains tested with the animal sera, evidence was produced of presumed infection of the animals at some previous time by *rickettsiae* of the North Queensland tick typhus. Tick typhus was not an important chapter in military medicine, but may well be one in the general history of typhus fever.

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CHAPTER 10

RELAPSING FEVER

RELAPSING fever, though not a serious military problem, caused considerable temporary invalidity among the men it attacked in the forces in Palestine, Syria and the North African littoral of Libya and Cyrenaica. Fortunately the type encountered was the sporadic tick-borne disease and not the epidemic variety carried by lice. As is well known, the infective agent is a spirochaete, causing irregularly recurring bouts of fever and with a predilection for attacking the central nervous system. The febrile attacks in themselves were not very different from those of several other pyrexial diseases. The temperature was often high and a rigor was common, particularly in the first attack, in which the temperature frequently exceeded 103°F. The primary bouts of fever usually lasted one to three days. The accompanying symptoms included severe headache, pain and tenderness in the eyes, photophobia, dizziness, pains in the joints and limbs, nausea and vomiting. Similar symptoms were seen in the relapses but usually they were then less intense. The most significant symptom was headache, which was practically always present and was characteristically intense and severe. Prostration was often considerable. Enlargement of the spleen occurred in at least a third of the cases. Tenderness of the spleen was a feature of the disease in some areas, particularly in Tobruk. Enlargement of the liver was less frequent; jaundice was only occasionally seen, and then usually in the most severe cases. The cervical lymph glands were sometimes enlarged. In a few patients erythema or scattered petechiae were observed on the skin, and herpes of the lips was not uncommon, particularly in the recurring bouts of fever.

Tick bites were found in at least a third of the patients when first seen: a small papule was present at each site and sometimes reactivation of these occurred during successive attacks. These bites were at first not noticed by the patient, since the ticks introduced a substance at the time of biting which acted as a local anaesthetic. This produced immediate analgesia in the region of the bite, thus permitting the adult or larval tick to feed undisturbed for its required period of fifteen to thirty minutes. This analgesia lasted up to two days. Clinical symptoms did not appear till five to eight days had elapsed after the biting. Relapses were usually, but by no means invariably, less severe than primary attacks; they generally lasted a shorter time, sometimes a few hours only. Both the number and the intervals between attacks varied. In many cases seen in hospitals in Palestine there were five or six relapses, but only one or two occurred in others. Higher numbers have been reported. The interval between attacks was sometimes as short as a few days, but could extend to a month or six weeks. Periodicity, though unusual, was occasionally a striking feature: some patients missed a cycle, only to relapse again later. During these intervals some patients remained well, but others had persistent

headache, malaise and general asthenia. Continuing headache was a significant symptom and was associated with residual infection of the nervous system in many instances.

COMPLICATIONS

The nervous system bore the brunt of most of the complications. Rigidity of the neck during the febrile stage and a degree of meningismus were regarded as part of the clinical picture; some actual involvement of the meninges was common and in rare instances the meningeal reaction was intense. Cranial nerve affections were not uncommon; sometimes these were not seen till months after the original infection. The commonest was facial palsy, which was occasionally bilateral. As a rule it resolved, but some permanent residual paralysis has been observed. Lesions of the 3rd, 4th and 6th cranial nerves were occasionally seen, causing ptosis or affection of eye movements. The 5th and 8th have been affected too in some epidemics, but no such lesions seem to have been observed in Australian soldiers. The frequency of these complications varied considerably in different areas. Among 68 men treated for relapsing fever in Tobruk, Cooper saw 7 facial palsies, and in addition 13 instances of meningeal involvement. Adler found only 2 patients with neurological complications out of 45 seen in Palestine before the war, but Scott in experiences with the R.A.M.C., found 9 out of 41. One of his patients was an Australian soldier who had right abducens palsy with meningitis; this man later had an upper motor neuron lesion affecting his left leg, but some months later appeared to have made a complete recovery.

Involvement of the spinal nerve roots occurred rarely: in one instance the 7th cranial nerve, and the 5th and 6th cervical nerves were paralysed. Encephalitic signs of wide variety were sometimes seen. Ataxia of movement and speech with other cerebellar signs have been seen.

Iridocyclitis also occurred. Hamilton saw 4 cases among 28 men infected in the Western Desert, but none in 63 patients from Syria. The possible significance of this will be discussed presently. Iridocyclitis yielded to rest and mydriatics and left no sequel. Papillitis was seen in a few cases in association with encephalitic symptoms; it too resolved, and no optic atrophy was observed.

The predilection of the infecting spirochaete for the nervous system is shown by the observations on the cerebro-spinal fluid. Lumbar puncture during the febrile period frequently showed the fluid to be under increased pressure. A pleocytosis was observed in about half the cases, and was often associated with moderate increase in the protein content of the fluid. The cellular increase was due to lymphocytes, but in some instances a small number of polymorpho-nuclear cells was found too. On a few occasions the cell count of the fluid reached over 400 per millilitre. Such changes were more frequently seen in patients showing signs of involvement of the nervous system. Occasionally spirochaetes were demonstrated in the cerebro-spinal fluid. Blood counts commonly revealed a moderate neutro-

phile leucocytosis, up to 12 to 15 thousand cells during the pyrexial periods.

DIAGNOSIS

The diagnosis of a primary attack was often difficult. Even the intense and sometimes persisting headache was not at first helpful in diagnosis, for it was also a feature of malaria, particularly of the malignant tertian type, and to a less extent of sandfly fever. Casualties from the Syrian campaign might have been suffering from any of these diseases. Combinations were seen too; M.T. and relapsing fever co-existed in several patients, thus complicating diagnosis. It was obviously important to demonstrate the spirochaete in the blood. This was not always easy to do as these organisms were scanty in the peripheral blood, but the pathological diagnosis was usually satisfactorily established if persistent search was made for spirochaetes in thick blood films. Such a search frequently had to be pursued into the apyrexial period, when it was often possible to find spirochaetes that were elusive during florid fever. Incubation of the blood was not found particularly helpful, nor was examination of the white cell layer of centrifuged citrated blood. In Syria, G. B. Hall and E. Ford tried the method of centrifuging a large amount of blood without any resultant improvement in diagnosis. Animal inoculation was definitely helpful in making a diagnosis, obscure by other means, but guinea pigs were difficult to rear in Palestine and the Lebanon and consequently were scarce.

In the history-taking of men with suspicious forms of illness, enquiry into their movements was often helpful, to discover whether they had been resting in rocky places or in caves or dug-outs, which were the common habitat of ticks in known infected areas. Review of individual histories sometimes made the diagnosis simple. Recurring attacks of fever of the appropriate pattern established a clinical picture which became quite distinctive when the involvement of an eye or one of the cranial nerves was added to it. There is no question that some of the alleged multiple attacks of sandfly fever, sometimes self-diagnosed, from the first Libyan campaign were due to relapsing fever. The morphology of the spirochaete was consistent with the usual descriptions, and its recognition gave rise to no trouble once it was found.

EPIDEMIOLOGY

The epidemiology of the disease had some interesting features. It was important to be sure of the nature of the vector. There was really no doubt felt that this was the tick-borne type of disease, but the possibility of the louse-borne variety was discussed at one time during the winter campaign in the Western Desert. There was little possibility of louse transmission, for this form of the disease is due to a different organism which does not indiscriminately use either vector. Clinical evidence in favour of the tick-borne variety included the sparse appearance of spirochaetes in the peripheral blood, the infrequency of jaundice, the shorter duration of primary

fever, and the greater frequency of relapses. Hamilton pointed out that the greater frequency of iridocyclitis in Tobruk than in Syria was curious, as this complication is commoner in the louse-borne type of the disease. The Tobruk series was, however, small, and the spirochaete is known to be a very mutable organism both with regard to the symptoms it produces and its immunological characters. The actual circumstances in which men were infected overwhelmingly pointed to tick transmission; ticks were found on the men, and they or their larvae infested many of the endemic areas, in North Palestine and Syria particularly. Adler and others in 1937 had previously described a series of forty-five cases from North Palestine, thirteen of which arose from infection in a single cave. Two medical men investigating the outbreak were attacked by larval ticks in the same cave and contracted the disease. One interesting episode during 1941 was the occurrence of relapsing fever in four Australian soldiers who had not been recently outside an area in Southern Palestine, hitherto believed to be free of the disease. Enquiry showed that they had on the same day visited a cave some miles away from any military camp.

It was believed that the tick vector in Palestine was the *Ornithodorus papillipes* (*tholozani*), and the organism the *Spirochaeta sogdianum,* possibly *S. persica.* The tick vector in North Africa was *O. erraticus* and the spirochaete *S. berbera.* The exact identity of the vector and spirochaete responsible for infections seen in the A.I.F. was not certainly established, despite the assistance of experts in the Hebrew University, for the difficulties of collection and transmission of specimens at the time were considerable. In the desert ticks were found in crevices and hollows of rocks, in Syria they frequented rocks and particularly caves. Both adult and larval ticks transmitted the infection, and as pointed out above, in spite of their lengthy feeding times, the larvae in particular were often not discovered for some time by reason of the painlessness of the bites.

TREATMENT

Treatment was not very satisfactory. It is interesting that during the 1914-1918 war arsenic earned a reputation as a specific, but in 1940-1941 its effect was on the whole disappointing. Arsphenamine was given in the form of "Neosalvarsan". The official instruction advised successive intravenous injections of 0.45 gramme, 0.6 and 0.6 gramme on the first, fourth and seventh day. It was thought better not to administer the drug during an actual paroxysm. Arsenic injections did not appear to prevent relapses so far as observation went. Accurate figures concerning the frequency of relapses and indeed the after history of patients have been difficult to obtain since the men were infected in widely separated areas, and frequently treated in numbers of different medical units. It was the general opinion of physicians that arsenic was not very successful in the local varieties of the disease, even allowing for the greater resistance to this treatment known to be a feature of the tick-borne disease when compared with the louse-borne variety. Therefore, as there was a prevailing shortage of arsenical drugs, the course given was usually limited to three doses.

Bismuth was used in some later series in 1942, eight injections being given alternating with five of arsenic. Limited experience suggested that this was perhaps of some value. There was no evidence that malaria lessened the liability to recurrences of relapsing fever.

In 1941-1942 A.I.F. hospitals in the Middle East treated 382 men with relapsing fever with no deaths; their average stay in hospital was 42 days. When men were free from symptoms and neither blood nor cerebro-spinal fluid showed any abnormality, and no fever had occurred for two or three weeks, they were considered to be convalescent and were treated as such.

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CHAPTER 11

FILARIASIS

FILARIASIS has been a subject of medical interest in Queensland since the pioneer work of Bancroft on the mechanism of its transmission. In the Pacific Islands it has also been studied and at the outbreak of war considerable knowledge had been gathered concerning the important endemic areas. In a review of entomological research in Australia Mackerras pointed out that in 1934, T. C. Backhouse had confirmed *Anopheles punctulatus* as a vector in New Guinea. It was known that there were at least two sibling species of *Wucheria* affecting man, differing widely in pathogenicity and apparently with different vectors. The nocturnal type of filaria was known to be widespread in New Guinea, but non-periodic forms were present also with a patchy distribution. The Australian forces were not exposed to substantial risk of filaria; though they were in some endemic areas, they were not committed in large numbers to prolonged exposure in the most highly endemic areas. Occasional infections would not cause a serious medical problem, but as the war in the Pacific spread out over wider zones, it was inevitable that the advancing Allied forces should occupy endemic areas and incur greater risks.

The Australian forces were therefore concerned with the possibility of infection in known endemic areas in New Guinea and New Britain. Here the well-known lesions could occasionally be seen in natives, particularly chronic lymphangitis due to the presence of adult worms or embryos, with thickening and dilatation of lymph channels, and oedema, with occasional febrile episodes. Associated with these lesions occurred the various forms of elephantiasis, occasional local abscess formation and chyluria. Embryos frequently could not be found in the blood. In more outlying islands in the Pacific such as the Society Islands, Cook Island, Samoa and Tonga the opportunities of infection were greater. Australian troops were not stationed in these islands, but American troops were, and in January 1944 the question arose whether it was desirable to station in Northern Australia American servicemen who had contracted the disease in Samoa, Tonga or elsewhere. The Combined Advisory Committee on Hygiene and Tropical Diseases was asked to express an opinion on this, and stated that, although it would not be desirable to station such men in Northern Australia, the risk to the civil population was not sufficient to warrant restriction of troop movements. This risk was not likely to be substantial, especially as the men infected showed no symptoms until nine or twelve months after exposure, and almost without exception had no microfilarial parasites in their blood.

Nevertheless the whole question was discussed later in 1944 at a meeting of the Allied Malarial Control Conference in New Guinea. At this meeting Major Backhouse described fully the method by which the filiform larvae developed in the vector mosquito and entered the skin of the human

host. Clinical conditions arising from the irritation of the presence of embryo worms, or of living or especially of dead adult worms in the lymph channels were important, as they suggested the possibility of filaria, even in the absence of microfilariae in the blood. The presence of subcutaneous or muscular abscesses, or of lymphangitis, with or without fever, funiculitis or orchitis might thus be significant, though filaria was not a likely cause. The so-called "tropical myositis", with recurrent abscesses, was probably non-filarial. More suggestive still were such lesions as lymph varices, or lymph scrotum and chylous exudates or chyluria due to obstruction of the thoracic duct. Backhouse recounted his own previous work in New Guinea which showed percentages of periodic blood infestation of natives rising from 20 per cent to over 40 per cent in some areas. This high degree of infection was combined with nocturnal periodicity and a very low incidence of elephantoid lesions, whereas non-periodicity and elephantoid conditions were common throughout Polynesia. Mackerras in the discussion stated that he believed that two distinct though indistinguishable races of filaria existed there. The cause of both periodic and non-periodic infection appeared to be *Wucheria bancrofti.*

From the military standpoint it was important to recognise that day-biting vectors such as *Aedes scutellaris* abounded in Polynesia, but in Melanesia night-biting vectors were important, such as *Anopheles punctulatus.* It seemed fair to assume that, though the risks of infection were present, Australian troops were not likely to be heavily exposed. Further, if any infections occurred they would probably be mild, resulting from exposure over a limited period, that is about a year, and these should recover gradually but completely during the following few years. From the standpoint of the clinician chronic glandular and lymphatic enlargements might arouse suspicion; in particular enlargement of the epitrochlear glands was important. In these milder types of infection only biopsy could establish the diagnosis, as microfilariae were not then found in the blood. In this connection the findings in American troops are of interest. Thompson, Rifkin and Zarrow studied 200 young soldiers in two years. In the early stages they only found recurring attacks of lymphangitis and lymphadenitis. Later mild recurrent oedema occurred, and in the last stage of early infection signs of obliterative fibrosis of lymph channels appeared. In none of these stages were microfilariae found, and eosinophilia was not of decisive help. Search for microfilariae was simplified in Australia and New Guinea by the knowledge that the periodic type of filaria showed nocturnal rhythm; the embryos were most likely to be found in blood films during two hours before and after midnight.

The Australian experiences of filaria were small. Records at the end of the war show that in the case of 22 men the diagnosis was made in Australia and in that of 2 men in New Guinea. These figures do not give any indication of the place of infection. Some of the men were Queenslanders, and it is quite probable that they acquired filaria before they joined the army. On the other hand there may be others who were subjects of a mild invasion of the parasite in which no definite diagnosis could

be made, and which apparently gave rise to no further symptoms. Sometimes unexplained enlargements of lymph glands were seen in men exposed to risk of infection; they may have been filarial especially if recurrent or associated with febrile episodes. As Australian soldiers were not exposed in large numbers to intense degrees of infection of a prolonged period it is unlikely that filaria will be of importance in their after history.

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(c) *Metazoan Infestations*

CHAPTER 12

ANKYLOSTOMIASIS

THE significance of hookworm infestation was clearly realised by Australian physicians, hygienists and pathologists long before the war, largely owing to the stimulation and assistance of the Rockefeller Commission. It was known to be endemic in the Pacific Islands, and infestation was expected among the troops once New Guinea became a combat area. In the Middle East it had not been a significant problem, though hookworm was known to be endemic in certain parts of Syria. Here, however, the most affected areas were near native settlements, and opportunities for infection were limited. Active military operations against Japan brought the subject into prominence. Hookworm was occasionally found among troops in New Guinea during the earlier war years, and by the close of 1942 the finding of ova in the faeces was not uncommon. In the Northern Territory of Australia, too, the Deputy Director of Medical Services issued a warning that the parasite was common among natives and that conditions were ripe for infection of soldiers. Preventive measures were taken to lessen possible contacts of bare skin, particularly of the feet with contaminated soil containing embryos hatched from hookworm eggs.

During and after the first New Guinea campaign ankylostomiasis was much more common, and routine microscopic examination of the faeces revealed ova in large numbers of soldiers returned to Australia either for wounds or overt illness or for rehabilitation.

The Medical Journal of Australia on 8th June 1943 reviewed the work done in the past on this disease in Australia, described governmental measures of action and control, and pointed out its possible importance in the future. Technical Instruction No. 53 was issued by the Director-General of Medical Services, Army, and later a supplementary instruction No. 73. The former of these pointed out that in a group of 130 patients with malaria examination of the blood showed eosinophilia in 31, and in 14 of these hookworm eggs were found in the faeces. Both on the mainland and in New Guinea the *Anchylostoma duodenale* and *Necator americanus* were known to be present: their life history was recounted in the instruction and the symptomatology described. Only the latter parasite was known to cause "ground itch". This eruption, chiefly affecting the feet, and less often the hands, arms and buttocks, caused great itching and burning with formation of vesicles within 48 hours, and later redness and swelling of tissues and a rash lasting some two weeks. The possibility of infestation by *A. braziliense* was also touched upon in this instruction, with its curious "creeping eruption". The general symptoms were, however, of greater importance; at the one extreme were the carriers, who merely exhibited eosinophilia and passed ova over a long period of months, and

at the other men with severe infections with intense fatigue, malaise, loss of weight, earthy pallor, epigastric pain and tenderness, enlarged liver, and, most important of all, severe anaemia, always of the microcytic type. Between these extremes lay the persons with the mild infections; even in these there might be infestation by some 500 worms. Abdominal discomfort characterised these, with dyspepsia, epigastric tenderness and anaemia, all of which might not become evident until after a latent period of perhaps six months.

At this time reports were received from all hospitals in New Guinea and on the mainland of the occurrence of ankylostomiasis. In the 17-mile area at Moresby at the 5th Casualty Clearing Station and the 2/9th Australian General Hospital both hookworm and ascaris eggs were frequently found in the faeces of soldiers who had been engaged in the recent campaigns, and similar results were later reported from other hospitals, the 2/5th and the 2/1st Australian General Hospitals near Moresby. Certain areas were found to produce the infection more than others. Buna, Sananda and Kokoda were evidently heavily infected, and many cases were also seen from Milne Bay, where the neighbouring villages were centres of infestation.

In Australia all hospitals in Queensland made similar observations. The syndrome described included eosinophilia, anaemia, epigastric discomfort and vague indigestion. A special report was compiled at the 117th Australian General Hospital in Toowoomba. Eosinophilia had attracted the attention of the physicians here and an investigation was carried out to ascertain the frequency of hookworm. Two thousand patients were examined, 1,600 of whom had come from New Guinea. One thick smear of the faeces was examined microscopically, and one specimen concentrated after the method of Willis. Repeated search was made only when gross eosinophilia was found, so that the incidence was certainly somewhat greater than that calculated. The average number of eosinophile leucoytes in the blood was 1,800 per cubic millimetre. In this group 800 were infected by hookworm, 18 by *Strongyloides,* 1 by *Ascaris,* 1 by *Trichostrongylus,* and 2 by tapeworm. The men concerned had been in hookworm-infested areas for periods ranging from a few weeks to 18 months, with an average of 4 months. In 50 patients a count showed that most of them had less than 20 female worms. Survey of the members of the military units to which these men belonged showed evidence of intense local infestation. In one instance 97 out of 99 in one unit were infected, and four brigades showed 60 per cent infection. In this series there was no history of ground itch. Except in one case anaemia was not present, but occult blood was usually found in the stools.

Culture of hookworm eggs was carried out by the staff of the Tropical School in Sydney: this showed that of 30 specimens examined half were *A. duodenale* and half *Necator americanus. A. braziliense* was demonstrated by animal experiments in two instances. In the early stages of this infestation cough was noticed in some patients, and X-ray films of comparable density demonstrated some temporary loss of translucency in the

perihilar regions, due probably to the changes associated with passage of larvae through the pulmonary circulation and air passages. Observations here and at other hospitals showed how little consistent was the degree of eosinophilia, which did not correspond with the density of the infection. Ova were occasionally found without any accompanying eosinophilia, and high eosinophile counts were found in patients who did not excrete demonstrable ova. At the 116th Australian General Hospital one patient was found to have 54 per cent eosinophilia.

At this time, 1943, it was believed that hookworm infestation would not prove of military importance, as the density of infection was relatively low, and the period of exposure was limited in endemic areas. Certainly little trouble was occasioned on the whole, and when the men recovered from relapsing malaria and other infections they were in good health as a rule, and were not anaemic. Some discussion arose as to the standard of cure. The treatment advocated officially was the administration of a specific vermifuge, tetrachlorethylene, carbon tetrachloride or oil of chenopodium, or a combination. After saline purgation the stools were examined, and if possible the worms counted. After 7-10 days, if re-examination of the stools showed that ova were reappearing, a further course of treatment was advised. One difficulty about this was that the drugs recommended were rather scarce, and hospitals had difficulty in obtaining all of them. Combinations of carbon tetrachloride 3 c.cm. or tetrachlorethylene 4 c.cm. with 1 c.cm. oil of chenopodium in an emulsion of magnesium sulphate in water were found to be most effective. These mixtures caused no toxic reactions and yielded up to 70 per cent of successful results. The best single drug was found to be tetrachlorethylene, but the addition of chenopodium improved it. The latter was supposed also to be useful for *Strongyloides* infestation, which was found in small numbers at this time.

Another difficulty arose in connection with repeated treatment. A certain proportion of persistent infections occurred, and the question was raised whether patients should be discharged when still passing hookworm eggs. It was neither practical nor desirable to keep them in hospital, as the number of worms they harboured was small, and constituted no special danger to themselves or others. Therefore the presence of hookworm ova *per se,* without any clinical signs of ill health, was not regarded as a reason for continued efforts to dislodge the last worm.

Later in the island campaigns more severe infestations of hookworm were encountered. These came from other areas, particularly in Bougainville. Early in 1945 the 2/1st Australian General Hospital reported that the number of cases was increasing, and a further increase was expected. Though many of the men had mild symptoms only, there were numbers seen who suffered from a very acute infection. This was apparently by the *Necator americanus,* as severe ground itch was experienced, usually on the lower part of the body, and coming on in a few minutes after contact with the soil of infected areas. In this area there was evidence of recent Japanese occupation, and it seems likely that heavily infested troops

had fouled the ground shortly before. Five to seven days after the itching cough was noticed, and later epigastric pain. Lieut-Colonel Sangster, of this hospital, records that this pain was sometimes quite severe, and that its onset was usually several weeks after the pulmonary symptoms. Searches for ova were not successful till over five weeks after the itch. Eosinophilia was as a rule of high degree. In a few instances ova were never found in the stools, as in one patient from 2,500 adult worms were recovered in four specimens. Higher worm counts have been found: one patient had 3,500. The most striking feature of this series in Bougainville was the occurrence of a few very acute anaemic states of rapid onset due to hookworm. In one, lung abscess occurred, and in several of these patients blood transfusion was necessary, as vermifuges alone were not sufficient to restore health even with massive doses of iron.

Similar experiences were reported from other areas at the same time. At Jacquinot Bay a survey showed an infestation rate of about 13 per cent. Eosinophilia was present in all infected men: similar degrees of eosinophilia were found in a series of men with skin diseases, but whether the two were related or not was not determined. At Aitape in the autumn of 1945 numbers of cases were also seen. Some men needed a couple of weeks in hospital, the symptoms suggesting a continuous syndrome. An irritating cough often persisted for several weeks after the removal of the worms from the alimentary tract. Two patients showed a radiographic picture of pulmonary infiltration which subsided within a month. A suggestion was made at this time that the increased incidence of hookworm in the 6th Division might account in part for the increase of malaria, assuming that the presence of the worms could hinder absorption of atebrin. No evidence of this was found.

During the operations in Borneo hookworm also occurred, the signs and symptoms conforming to the usual pattern. An attempt was made to hatch worms at Balikpapan, but without success, so the type could not be ascertained. Bougainville appeared to be the most heavily infested area occupied by the Australians in the South-West Pacific Area.

Some of the important points emerging from these experiences with *Ankylostoma* are the need for thinking of hookworm in the presence of eosinophilia, for realising that heavy infestation may be present even though ova are not found in the stools, and for remembering that this may occur even within a comparatively brief period if the degree of infestation of the local area is sufficiently high. The indications for treatment were taken to be the finding of ova, unexplained eosinophilia, with abdominal symptoms, ill health or anaemia.

Infestation rates varied: a survey of the 1st Australian Infantry Brigade showed a rate of 28.5 per cent. In some individual units the rate was much higher; the risk of infection from natives was illustrated by the finding of a 100 per cent infection rate in the Angau Hospital at Finschhafen in 1944. Infestation rates also varied according to the stage at which patients were examined. For instance, "tropical eosinophilia" appeared at Tarakan, with gradual onset, malaise, fever, colicky upper

abdominal pains, nausea and vomiting. The liver was tender but not enlarged, and eosinophile cells varied in number from 11 to 84 per cent of total leucocytes. Nothing else was found, but of the diseases endemic in such areas hookworm was the most likely.

The 8th Division as prisoners of war also suffered from hookworm. Dunlop records that 20 per cent of men examined in camps in Tamarkan, Chungkai and Tamuang in Thailand had hookworm. During the wet season this percentage increased; this was not surprising, as many of the men had no boots and worked barefoot. Here, too, infection by *Strongyloides stercoralis* was very prevalent, affecting about half the men. At Nakom Paton in July 1945 Fisher noted an outbreak of ground itch. Thirty men who had been working in a vegetable garden manured by human faeces simultaneously complained of intense itching of the feet. Many of them had a vesicular eruption. After several days they had an acute respiratory disturbance with substernal discomfort, fever, and cough with occasional sputum, but no objective signs in the lungs. A few instances of creeping eruption of the feet were seen.

During eighteen months at the hospital at Nakom Paton *Strongyloides* was the commonest incidental finding in hundreds of microscopic examinations of stools. It was suggested that this may have caused the creeping eruptions as *Ankylostoma* was uncommon there.

There were, of course, great regional variations in the distribution of these parasites. After the liberation of these prisoners those who passed through the 2/14th Australian General Hospital were examined for intestinal parasites, and the percentages of infestation found were *Ankylostoma* 25 per cent, *Ascaris* 12 per cent, and *Strongyloides* 8 per cent.

STRONGYLOIDES STERCORALIS

This worm has been mentioned already. It was found in many men coming from many areas in the South-West Pacific and South-East Asian zones. A study of sixteen cases of this infestation was published by Lowe and Lancaster. They pointed out that the parasite is known to exist in Queensland. Heydon and Green in 1931 found white people in the Atherton Tableland to be infected, and it has been occasionally reported elsewhere. Though resembling *Ankylostoma* in its general habits it has been found more resistant to treatment, and therefore more prone to give rise to sequels which are truly recurrences. The ova hatch before or shortly after entering the lumen of the bowel, and as a rule are seen only after diarrhoea or purgation. Rhabditoid larvae are produced which become filariform, usually after evacuation, and at this stage are able to penetrate the skin. Re-infection may occur by the larvae entering through the perianal skin, thus perpetuating the cycle. Erythema or petechiae may be produced in the skin or perianal region like ground itch.

In the 117th Australian General Hospital Lowe and Lancaster found about a quarter of the patients had some skin irritation at the time of infection. Pulmonary symptoms and abdominal discomfort were common.

Eosinophilia was usually of a higher grade than with *Ankylostoma,* ranging from 1,100 to 12,600, with an average of 4,300 per cubic millimetre.

Treatment was more difficult than for hookworm. Gentian violet was tried, 1 grain thrice daily for two periods of eight days with a week's intermission, also preparations of antimony and emetine, as well as the usual vermicides, but the results were not very satisfactory. As with hookworm some residual worms were hard to dislodge, and the possibility of reinfection made cure hard to attain.

In Burma and Thailand the risk of infection was great as can easily be seen, and treatment being limited by slender and often absent resources, recurrences were common. At Ye in Burma investigation showed a 50 per cent infestation rate. Even simple preventive measures such as protection of the feet were difficult to carry out. Observation of men with relapses has shown that abdominal disturbances are common, including diarrhoea. Associated infections by *Entamoeba histolytica* have been found fairly often. A series of 30 men who had worked in muddy unhygienic conditions in Thailand were investigated. All had diarrhoea of compulsive type, but had a history of dysentery. Microscopic examination revealed larvae in 24, larvae and ova in 5 and ova only in one. The rhabditoid larvae were sometimes seen up to 70 per field. More evidence of infestation was found where mess orderlies were infected.

ASCARIS LUMBRICOIDES

This round worm was occasionally found. In Burma and Thailand it was not uncommon as the figure quoted above for one area shows. In Syria the incidence among the native population was known to be high; it was reported to vary from 5 to 35 per cent in various areas. Abdominal disturbances and vomiting sometimes appeared to be caused by this worm. Treatment was not always satisfactory, even with the recognised vermifuges. Santonin was not always obtainable, but was as a rule effective. Oil of chenopodium was believed to be more effective for *Ascaris* and *Strongyloides* than other drugs, hence its inclusion in the "cocktail" draught usually employed. Gentian violet, introduced into the Middle East formulary for thread worm infestation was also tried, but without apparent success.

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CHAPTER 13

SCHISTOSOMIASIS

THE experiences of the 1914-1918 war showed that *Schistosoma* infection (*Bilharzia*) was a danger in Egypt. The Second A.I.F. was therefore alert to minimise the risk, though Egypt was not used as a training area as much as Palestine. On one occasion what was believed to be a single ovum was found in the urine of one patient in Palestine, but the lack of history of exposure and the fact that urinary symptoms arose within six months of arrival disposed of a diagnosis of schistosomiasis.

Early in 1941 attention was drawn to a section of the 2/1st Field Company, R.A.E., which had carried out exercises some months previously involving the pumping of canal water at Helwan and Sidi Ghazi. One of the men was treated in No. 1 New Zealand Hospital for schistosomiasis. He gave a history of exposure of his hands and legs to the water and as a number of other men had been similarly exposed the section was pathologically surveyed. Forty-three men were examined and two others were found to be passing ova of *S. haematobium* and red cells in the urine and to have 18 per cent eosinophilia. As a result the Australian forces in Egypt were warned of the risk. The Director of Medical Services, A.I.F., suggested that exercises involving pumping of water should be prohibited and that precautions should be taken. Instructions were also promulgated in the 9th Australian Division in 1941 prohibiting bathing in unauthorised streams. Infection by the *S. haematobium* or *S. mansoni* did not prove an appreciable risk in the Middle East.

When the centre of military activity shifted to the South-West Pacific the question of infection by *S. japonicum* was raised. The more serious and resistant lesions caused by this Asiatic form of *Schistosoma* were not likely to be encountered in the earlier campaigns in New Guinea, as its distribution began at the Philippines and spread north and east from there. The disease had not been reported from the Solomons or New Guinea. There was, however, a danger that Japanese troops might carry the infection with them and transmit it to vector snails in other islands. In 1943 an alarm was raised by a report that three American servicemen had been discovered to have bronchitic symptoms due to this Asiatic type of blood fluke. The areas involved were Buna and Guadalcanal. Fortunately this was a false alarm, as the diagnosis was not substantiated, but a full technical instruction (No. 40) was issued by the Australian Army Medical Services. Although it did not appear likely at the time that *Schistosoma japonicum* would give trouble in the Australian combat areas, the importance of the parasite lay in the severe symptoms it can cause, and a full account was therefore given in the instruction. In this, four stages in the clinical picture were distinguished, (1) skin irritation, (2) toxic or anaphylactoid features, (3) dysenteric symptoms and (4) portal cirrhosis, developing at a much later stage. The life history of this parasite

follows the same general lines as that of other blood flukes. The active miracidium, which may be seen in viable eggs, escapes in water in its free swimming state and invades certain fresh water snails, its first host, from which cercariae emerge later capable of entering the human skin. The cercariae thus enter the peripheral veins and pass through the pulmonary circulation into the systemic arterial system. Those reaching the mesenteric capillaries pass through the portal system, and become mature in the portal vein within the liver. Mature worms pass back down into the small mesenteric veins, and there deposit ova in the intestinal wall. The adults in the portal system may survive for many years, and can produce thousands of eggs which are packed in the surrounding venules, and may gain the lumen of the bowel and appear in the faeces. The deposits of ova may further cause nodule formation in the tissues of the human host, and in the colon papillomatous growths are formed which can be seen on sigmoidoscopic examination and yield ova for identification. The characteristically lateral knobbed ova may be found in the mucus from the hyperaemic colon, or in material obtained by scraping the "pseudo-tubercles" on the colonic wall. The danger of this form of schistosomiasis lay in the peri-portal cirrhosis set up by the parasites in the liver, which could be produced insidiously long after the human host had apparently recovered from the warning symptoms of invasion. These symptoms were misleading unless suspicion was aroused and might be mistaken for those of other febrile diseases, just as the nodules on the wall of the bowel might be mistaken for those of amoebiasis unless careful microscopic examination was made. Exact diagnosis was made by the finding of the ova in the faeces, but in surveys of persons exposed to infection the constant and high eosinophilia was of great value, and also if antigen was available, the immunological reactions of the skin to intradermal test, and of the serum to complement fixation. The march of symptoms in the early weeks was also highly suggestive; urticaria or other allergic manifestation, cough and signs of bronchitis, abdominal pain and tenderness, and a few months later, dysentery. Occasional systemic distribution of the nematodes could cause cerebral symptoms.

Fortunately the threat of an outbreak of this disease was never repeated in the islands south of the Philippines. But at Leyte several hundred men of the American ground forces and of the R.A.A.F. were attacked. Schistosomiasis had been recognised on Leyte long before the war, and a warning had been given in a terrain study (No. 84) published by the G.H.Q. Geographical Section, which pointed out that the vector was a fresh water snail (*Blanfordia quadrasi*) and that swimming in fresh water in infected areas was dangerous. A squadron of the R.A.A.F., No. 3 Airfield Construction Squadron, which was attached to the American forces, staged at Leyte en route for Mindoro. Local enquiries produced assurances that the inviting water in a river flowing past the camp was safe, and it was used for swimming and washing clothes. No vector snails were found in the vicinity, but it was later found that the distribution of snail breeding places was so patchy that failure to find snails in any one place gave

no foundation for safety. In any case the snails preferred small slow running streams. By the time the clinical symptoms were manifest most of the men had moved with the unit to Mindoro. The early febrile period was at first put down to sandfly fever, but soon schistosomiasis was suspected, and the 560 Australians involved were examined. Nearly half the number were found to have eosinophilia, and therefore were suspect. Another Australian unit on Leyte, the 6th Wireless Unit, was also reviewed, but no sign of schistosomiasis was discovered.

The commonest symptom found among the infected men in the early stages was fever, reaching a high peak, sometimes 104°F. or 105°F. in the afternoon. Skin irritation was not a feature of this outbreak. Abdominal pain was occasional only, so too was paroxysmal cough. Pain in the neck with some stiffness was complained of by most patients: a suggestion was made that the pain was referred from the diaphragm or liver when these were penetrated by the cercariae. Urticaria was not uncommon. Eosinophilia was constant, and reached a higher average level than in other common worm infestations. Ova were difficult to demonstrate in the bowel contents, but could be found in the small, white granules sometimes seen on the mucosa of the colon. The number of eggs found was usually small: when immature eggs were found mature specimens could be found at later examination. Concentration methods were employed, allowing each emulsified and stained specimen to settle repeatedly after dilution and rejection of the supernatant layers. In each mature egg a miracidium could be seen in contractile activity. Sedimentation methods were found to be better than flotation with zinc sulphate, as they did not kill the miracidia or distort the ova. Only a small percentage of the ova had spines, owing probably to the peculiarities of the Filipino strain, which seems to resemble the Chinese strain, and perhaps to the partial or complete disappearance of the spine as the embryo grows in the egg. Immature forms were smaller and darker than the mature, and predominance of the immature ova was found to be a feature of the mild infections.

No deaths occurred among the Australian airmen, but among a number of severe and acute infections of Americans there were two fatalities. The handling of the affected men aroused considerable discussion. On the one hand, the R.A.A.F. felt that the unit was isolated, was carrying out very good work with a high morale, and that most of the men did not feel ill, and their mild infections could be treated while they continued to work. On the other hand the U.S.A. troops affected were mostly sent to the 118th General Hospital on Leyte, where all facilities existed for full investigation by the staff or by a special Schistosomiasis Commission. More detailed references to the administrative problems involved are made in the Air Force Medical History (Volume IV). It may here be pointed out that it was recognised that accurate diagnosis was desirable, but that psychoneurosis could be caused by retention in hospital of men who felt quite well. The question at issue was the reconciliation of these aims.

For treatment Fouadin 40 c.cm. in nine injections was at first used in the field, and was given to all men with eosinophilia of 10 per cent or

over even if ova could not be demonstrated, but shortage of supplies did not permit treatment of all men possibly exposed. Examination by members of the U.S.A. commission on schistosomiasis showed that of 41 untreated men diagnosed as infected 10 were excreting ova, and of 42 treated 4 were still excreting ova. Treatment was resumed, tartar emetic being used. The unit was then moved to Morotai and thence to Balikpapan where 19 new infections were discovered. Finally investigation of the whole unit was carried out at Somers near Melbourne under the direction of Group Captain A. H. Baldwin, and with advice from Brigadier N. Hamilton Fairley. Fairley's extensive experience in schistosomiasis in the 1914-1918 war and the following years was of great value, and he supplied an antigen for tests which, though 18 years old, was still potent. Later while in England he sent out his stock of infected snail livers, but unfortunately the ship carrying this material was lost. The supply of antigen was nearly exhausted by this investigation, but useful results were obtained. W. P. H. Dakin and J. D. Connellan have described the full investigations of these men and F. E. Williams of the Walter and Eliza Hall Institute the results of the complement fixation tests. The clinical histories over a period of twelve months were reviewed, and the special methods of examination were carried out. A fuller account of this work will be given in the history of the R.A.A.F. Medical Services; the findings may here be summarised as follows: In all 226 men were treated. In arriving at a diagnosis stool examinations were found of great value, though ova were scarce, and often could not be found except by sigmoidoscopy, which however was not used in the early stages of infection. A standard sedimentation procedure was used, based on the lines recommended by the United States commission on schistosomiasis, whose members gave great help in the enquiry in the field. Eosinophilia was found a most valuable sign; in a small observed series the eosinophile counts fell to normal as cure was established, as judged by other tests. Eosinophilia did not exactly parallel the intensity of the complement fixation tests, but it was found sometimes when no ova could be found. The same applied to complement fixation. Such evidence was regarded as sufficient to warrant a course of treatment. Twenty-two men who had received a course of treatment for suspicious signs were later found to respond to the complement fixation test, though no ova could be found. Though it was probable that they had been cured a routine course of tartar emetic was given. Men with a positive response to serum tests and no other signs were also treated. This delicate test was found of definite value, and disclosed some infections that would otherwise be missed. The presence of the test in the absence of other signs was thought to be due to an abortive infection, unisexual infestation, or spontaneous death of the worms.

In treatment Fouadin was disappointing: 103 men out of 177 suspected infections relapsed after its use. Tartar emetic was then used, giving a total of two grammes, in one per cent solution. It was found that a course could be given by daily injections, taking two and a half weeks in all without causing toxic symptons. The prognosis of these men should be good.

It was an unique opportunity to institute treatment of this disease so early, and the existence of serious late lesions in the untreated or chronically infected should not give rise to pessimism in this experience. When the men were discharged they were brought under the care of the Repatriation Department, and continued observation will be made as necessary. There is no risk of spreading the infection in Australia.

Considerable impetus was given to the study of this disease, and information was distributed to pathologists and hygiene officers of the army and to commanders of mobile bacteriological laboratories to enable them to cope with the problems of diagnosis. The importance of full medical intelligence of newly entered tropical areas is obvious from this outbreak, also the need for certainty of pure water supplies. In March 1945 steps were taken to promulgate these warnings and the precautionary methods necessary in areas where this disease might present a problem new and potentially troublesome to the armed forces.

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CHAPTER 14

BRUCELLOSIS

ONLY a few instances of brucella infection occurred in the Australian Services. As knowledge of this infection has progressed greatly since the original work on Malta fever it is now recognised that brucellosis has a world-wide distribution among cattle and swine and occasionally attacks man. It is interesting but not unusual that at least one infection of a member of the A.I.F. in the Middle East took place, though opportunities for drinking raw milk were limited there. In Australia a few cases appeared also, just as they might in the civil community. Several of these infections were contracted on the Atherton Tableland in Queensland. Clinically the diagnosis was sufficiently convincing, but bacteriological proof was difficult to obtain. The long sustained fever with a progressive loss of weight, a moderate degree of toxaemia, polyarthritis and other metastatic complications such as orchitis made a characteristic picture. Culture was not successful, possibly because its importance was not realised in the early stages of fever. Agglutination was not always a convincing diagnostic method, either because of the need for a number of trial strains of the *Brucella abortus,* or because of low concentrations of agglutinins. In two instances the serum agglutinated the organism to a dilution of one in two thousand or more, but in two others agglutinations did not take place below a dilution of one in eighty or one in one hundred and sixty. Sulphonamides were tried in treatment; the results were equivocal, but the experience was too limited to be of value.

CHAPTER 15

CEREBRO-SPINAL MENINGITIS

MEMORIES of the epidemic violence of cerebro-spinal meningitis during the 1914-1918 war and of its high mortality rate at that time were still fresh in 1939, and were not altogether dispersed by the knowledge that powerful specific drugs were now at hand. From August 1914 up to the end of June 1916 no less than 256 recruits had died of the disease out of 604 affected, and the incidence in young soldiers was then five times that among the civilian population. General R. M. Downes and Dr J. H. L. Cumpston, fully aware of their responsibilities to the army and the civilian population, knew the potential risks in 1939. For twenty years there had been a very low incidence of cerebro-spinal meningitis in Australia. Thus a non-immune population of young adults had grown up, and study of the disease showed that it was affecting a higher age group than before. Young recruits in the armed Services would soon acquire immunity by nature's methods, but the attendant perils were not negligible.

The first case in a military camp appeared on 6th December 1939, at a time when the concentration of recruits in camps was beginning to attain some density. It was recognised that the ever-smouldering disease would certainly increase its activities in the civil population also, owing to the alterations in life and domicile and other social changes brought about by the war.

As was expected, similar conditions produced a wave of meningitis in Britain, and the Australian Medical Liaison Officer in London sent particulars of the precautions adopted there with regard to breathing space per man in sleeping huts and tents. In Britain in 1939-1940 it was the group I type of meningococcus which showed epidemic activity, while the group II was more usually found in carriers. However, in Australia as elsewhere there was no intention of attempting to identify carriers as was done with such thorough intensity during the 1914-1918 war. In England and France in 1939 observations of a large series showed that wholesale swabbing of contacts served no useful purpose. Since meningococci in the naso-pharynx of carriers disappeared after five days' treatment with one gramme of sulphanilamide given three times a day, the problem was simplified even if localised outbreaks should occur. It was further realised that even the information that certain "contacts" carried meningococci in their throats and noses helped little in forecasting possible outbreaks of clinical disease.

INCIDENCE IN AUSTRALIA

In 1940 emphasis was laid on early recognition of cases of meningitis, both from the therapeutic and the prophylactic points of view, and all medical services were insistent on the need for adequate air space in sleeping quarters. Respiratory epidemics would also certainly appear in the camps, particularly in the colder months of the year; these were a

warning of the possible appearance of cerebro-spinal meningitis, and their presence would mask the early mild coryzal manifestations of meningoccal invasion. Occasional fulminating infections of meningeal and septicaemic type were likely to occur too, and as the death rate of these is always high, constant surveillance of the position was necessary. Contrary to popular belief the concern of the health authorities was more felt for civilians than servicemen, for the proportion of severe infections and of deaths is lower in military establishments than in civil epidemics, by reason of the higher degree of vigilance and discipline in the armed Services and their more favourable age groups.

Seasonal distribution of cerebro-spinal meningitis had not been very noticeable in the civil population of Australia during the ten years before the war; it was slightly more prevalent in winter and spring. During 1940, however, under wartime conditions a rise during the winter was expected. By the end of September twenty cases had been notified in army camps. These were distributed in ones and twos over the various camps in all commands, with the exception of eight from one camp, Northam, in Western Australia. Most of them occurred in the late winter and spring. Even with these very small numbers some interesting features had been noted. One hundred and one cases had occurred in the civil community from January to September 1940, double the average yearly incidence of previous years, and a definite rise was perceptible in the 3rd Military District (Victoria) during September. Colonel M. J. Holmes, Army Director of Hygiene, correctly predicted that a rise in military camps in Victoria would follow the increase in civilian cases. A proportionately small incidence was observed in air force camps also, but this too was now tending to rise. In no instance did more than one case appear in the same unit. These observations are of interest, and illustrate how even a small series of figures, dealing with a disease usually of sporadic habit, can be most informative, even when scattered over so large an area as Australia. The relative activity of the disease among civilians was taken as a warning that there was a possibility that epidemic spread might occur in the camps, where conditions were more favourable to such a development. At the same time Colonel Holmes pointed out that provided all care was taken to secure good hygienic conditions and to detect clinical outbreaks immediately, the massing together of young susceptible persons in almost closed communities would assist the natural process of immunisation.

At the end of 1940 an alarm occurred at Darwin. Early in December a naval rating died of an illness diagnosed as cerebro-spinal meningitis and following this other suspicious cases occurred. The Commonwealth Medical Officer quarantined the barracks and took measures to limit close contact of numbers of people, as in hotels and cinemas. The army and air force medical services supplied additional medical officers and nurses, and a pathologist was sent to investigate. Considerable difficulty was experienced in avoiding contamination of cultures owing to the prevalence of dust and the humid heat. In the ensuing two months over 140 patients

were observed who had an illness characterised by rapid onset, pains in the head and back, some stiffness of the neck and a morbilliform rash. There is no doubt that this illness was due to dengue fever and that it was at first mistaken for meningitis. Stiffness of the neck muscles and severe aching in the back of the head and neck have in some epidemics of dengue fever given reasonable cause for suspecting meningeal infection. This false alarm did good in emphasising the need for prompt investigation.

By the end of 1941 the disease had passed through a phase of increased activity, but was then beginning to wane. It never reached alarming proportions, but it was expected to show recrudescence again during the winter and spring of 1942, though on a lower level. In the first two years of war numbers of cases reported in Australia were as follows:

Army	215
R.A.A.F. . . .	45
R.A.N. . . .	9
Civilians . . .	1,125
Total . . .	1,394

The distribution between States was proportional to population, except in Western Australia, in which 481 civil and 104 service cases occurred. Dr J. H. L. Cumpston, Commonwealth Director-General of Health, had the subject discussed at a meeting of the National Health and Medical Research Council in November 1940, and at this and at a later meeting in 1941, Colonel Holmes presented a complete analysis of the position. An instructive point was noted with reference to age incidence. During 1931-1939 age distribution had been noted only in New South Wales, and here 23 per cent of cases occurred over the age of 15 years; in 1940 this percentage rose to 45, and in 1941 to 56. In the other States this figure varied from 49 to 91, with an average of 60.

The experience of two years showed that the epidemic did not begin in military camps and spread to civil population, since the civil occurrence of the disease preceded its appearance in camps. Further, during the summer months the disease tended to die away in camps, but remained active among civilians. Decline in the military camps was found to anticipate and forecast a later drop in the civil community. In most of the camps only isolated cases were still occurring. At first the preponderance of infection was in the metropolitan areas, but during the second year a wider spread occurred in rural areas. This too was an evidence of the widened spread of the infective agent, and therefore of the process of immunisation, which it was confidently expected would terminate the epidemic. The mortality in the defence forces was low: up to September 1941 it was 2.8 per cent in the authenticated cases. Incomplete figures for the various States at this stage showed a civilian death rate ranging from 20 to 24 per cent.

During this 1940-1941 period the recognised factors affecting the incidence of meningitis in camps were given careful attention. A higher standard of hygiene in the camps was achieved than in 1915-1916, though all that was desired could not be obtained, as it was difficult to have precautions enforced. The lag of accommodation behind the numbers of recruits, perhaps inevitable in a country unprepared for war, was at times a cause of definite and even serious anxiety. The lack of sufficient space both in rural and semi-rural camps and near metropolitan areas forced the use of areas such as showgrounds, many of the buildings used being intrinsically unsuitable for sleeping quarters. Though over-optimism and perhaps some lack of realism even in military circles were an occasional cause of overcrowding and other defects of accommodation, the pressure of medical opinion helped to raise and maintain camp hygiene. Even in a country like Australia, on the whole favoured climatically, extremes of heat and cold are encountered, and the "toughening" process of training requires some discretion at first when local conditions are not favourable.

Anxiety had been felt by the D.G.M.S. and his staff since the beginning of 1940 about the living and sleeping accommodation in camps, and in August 1940 a special instruction forbidding overcrowding was issued by the Military Board and strictly enforced. Steps were taken too to modify training so as to avoid undue exposure and fatigue. This was specially necessary in view of the large numbers of universal service trainees who were entering camps for short periods of training, as their physical standards were lower than those of A.I.F. volunteers. Not more than six men were allowed in a tent 12 feet by 14 feet, and not less than 45 square feet space per man in huts, nor less than 5 feet between the centres of beds. These figures were arrived at by compromise, for the accepted standard floor space is 60 square feet, and bed distance 6 feet. Care was taken to air huts and bedding, and no overcrowding was permitted in canteens, recreation huts and cinemas. Medical officers were instructed to institute immediate isolation of men suspected to have meningitis and to ensure prompt energetic treatment, and to keep immediate contacts under surveillance. Isolation of immediate contacts was carried out only at the discretion of the medical officer. (See appendix.) Fulminating cases were still occasionally seen at the close of 1941, but their number was dwindling, an indication either of rising immunity or decreasing virulence. At the end of 1941 there were still evidences of activity in the disease. Even in the summer months the incidence was much higher than the average over the preceding ten years, but with the exception of the temporary and moderate rise in Western Australia infection had remained sporadic in distribution.

IN THE MIDDLE EAST

Meanwhile in the A.I.F. in the Middle East the problem had also arisen. An occasional case occurred among troops in transit by sea, and it was to be expected that the infective agent, if not already present in the force, would be brought from Australia. However, the conditions were

favourable in the training camps, both with regard to climate and camp accommodation. A small outbreak occurred in Palestine in the last few months of 1940. The first three cases occurred in a survey company of a railway construction unit at Nablus. Precautions were taken to avoid overcrowding in all ways, and no further cases occurred. Others were reported from separate battalion areas: as is usual in this disease, no common cause was evident. Care was taken to secure adequate dispersal in tents and billets, messes and amenity huts. No outbreaks of importance occurred. The total incidence in the A.I.F. in the Middle East was as follows:

1940	16 cases with 1 death
1941	66 cases with 2 deaths
1942	3 cases with no deaths

The actual incidence of proven meningococcal infections may have been lower, as all the above were not bacteriologically proved. Lymphocytic benign meningitis is not included. In addition there were 15 cases in the A.I.F. in the United Kingdom with no deaths. The incidence rate in the A.I.F. overseas did not exceed 1.2 per 1,000 per year in 1940 and 1941.

In 1943, when all troops had returned to Australia from the Middle East, cerebro-spinal meningitis still required to be carefully watched. During 1942 the great expansion of military camps throughout Australia and the increase of all the Australian and Allied armed forces in Australia enhanced the risk of outbreaks. The figures were now large enough to allow a more accurate idea of the mortality rate to be formed, and an investigation was carried out at army medical headquarters to ascertain the corrected rate, and to determine, if possible, the importance of sequels.

The figures obtained from 2nd Echelon for the army showed that up to 31st December 1942 646 cases of cerebro-spinal meningitis had been recorded in all areas with 57 deaths. Analysis of the case histories of the men who died showed that 14 deaths out of the 57 were not due to cerebro-spinal meningitis, that is, due to the meningococcus, but to other forms of meningitis, such as tuberculous, streptococcal or post-traumatic. This was purely an error in classification. The corrected figure of 632 cases with 43 deaths gave a mortality rate of 6.7 per cent. It is of interest that in Sydney, where all military patients from the metropolitan area were treated for meningitis at one civilian hospital, the Prince Henry Hospital, the death rate excluding a few moribund patients was 5 per cent, whereas the civilian death rate in New South Wales was then about 12 per cent. It was obvious from the study of the case histories of this military series that the diagnosis was frequently not simply made, particularly when the symptoms were aberrant or mild, or at the other extreme, rapid and severe.

Though the official instructions stressed the need for the invariable administration of a sulphonamide drug in high dosage at once when suspicious symptoms were noted, even before lumbar puncture was performed, the importance of these measures had not always been realised. Half the fatalities occurred in men stricken down quickly, and one-third

of the deaths took place within twenty-four hours of the onset. More difficult to estimate was the degree of morbidity following the illness. Of the 587 men who recovered 352 were still classified "A", 70 as "B", and 104 as unfit for service: 48 had not been reclassified, and 13 were not recorded. Of the 104 unfit, examination of the records showed that 14 were classed "D" by reason of a disability not related to meningitis: 24 were found unfit because of some sequel of the illness, and 66 could not be assessed from the available records.

It was found that medical boards often gave no reason for their decision. Even "post cerebro-spinal meningitis syndrome", sometimes used as a self-sufficient clinical diagnosis, is meaningless unless amplified by further description. The impression given by the records perused was that lowering of the classification was not always defensible. The same subject was reviewed also from time to time in convalescent depots. It was found that where medical officers were particularly interested in the rehabilitation of men convalescing from meningitis the results were correspondingly better. This question will be discussed in connection with treatment. The later years of the war did not add anything specially to the subject. The better supply of powerful sulphonamides, particularly in soluble form suitable for infection, and more widely diffused knowledge helped greatly in securing early and efficient treatment.

IN THE SOUTH-WEST PACIFIC

The Pacific war did not produce conditions in which meningitis flourished, but at least some of the lessened incidence was due to an increase in the general level of immunity in the community. One outbreak occurred which illustrated that the introduction of the active organism into suitable soil will produce the disease. In June 1944 some 300 recruits arrived at Wampit in New Guinea in an area where cerebro-spinal meningitis had broken out among local natives. These troops were not of good physical types and were suffering from a respiratory infection. Soon a death occurred from cerebro-spinal meningitis, and another severely ill man was rescued by early large doses of sulphapyridine. Wider dispersal of the men in their living quarters and mass treatment of native and Australian troops with sulphapyridine and sulphathiazole for two days checked further spread.

The figures for the whole of the Australian Army in Australia and the South-West Pacific Area are as follows:

	Australia		South-West Pacific	
	Number of cases	Rate per 1,000	Number of cases	Rate per 1,000
1942	448	1.24	16	0.74
1943	106	0.27	6	0.07
1944	30	0.08	2	0.02
1945	11	0.05	10	0.07

Several cases of meningococcaemia of the benign type were reported from the Royal Australian Navy Hospital, Canonbury, Sydney, and a

special technical instruction was issued in view of the possibility that other instances of this infection might occur in naval establishments. The onset in these was often insidious, and intermittent periods of pyrexia with sweating and pains in joints and muscles were observed. The direction was given that such symptoms without obvious cause were sufficiently characteristic for a clinical diagnosis. This was made more probable by the appearance of crops of rose-pink macules with haemorrhagic centres during each episode, especially if the muscles and joints were tender, even with small joint effusions. *Erythema nodosum* has occasionally been observed also, as a misleading sign suggesting rheumatic fever. Neutrophile leucocytosis and distribution of the rash about the wrists, ankles and fingers were further confirmatory signs.

In a different category were the fulminating blood infections, where the patient's best chance of survival lay in the immediate administration of a large initial dose of a soluble sulphonamide in an intravenous infusion. Where this could be promptly done some dramatic recoveries occurred. The diagnosis was usually clinical, inasmuch as the appropriate treatment was administered immediately reasonable suspicion was entertained. Army Technical Instruction No. 6, dealing with fulminant meningococcal infection, directed that toxaemia in a patient with widespread purpuric rash was to be regarded as sufficient evidence on which to base treatment.

A special caution was given against regarding a normal cerebro-spinal fluid as excluding the septicaemic variety of the disease. The number of cells found in the fluid naturally depended on the intensity of the meningeal reaction. Occasional instances of the Waterhouse-Fredericksen syndrome were seen, where intense haemorrhagic spoiling of the adrenals was found at autopsy.

A correct clinical diagnosis was at least once made by a relatively untrained orderly, who observed head rigidity and a faint rash in a patient admitted to a tented hospital ward during the night with a provisional diagnosis of pneumonia.

Although precipitin tests on the cerebro-spinal fluid have been found useful by some for quick diagnosis, immunological tests in general were not relied up on in the Australian services. Bonnin and Bryce recorded their findings in a series of complement fixation tests in meningococcal infections, but found that false positives occurred, and also cross fixation with gonococcal antigen. Blood cultures were sometimes, but not always, helpful: in subacute or chronic septicaemic infections clinical and therapeutic trial were the best practical methods.

TREATMENT

At the outbreak of war treatment had become a question of prompt and efficient dosage with a suitable sulphonamide. For the first two years sulphanilamide and sulphapyridine supplies were restricted, particularly of the injectable forms, and there is little doubt that several severely ill men in hospital owed their recovery to the zeal with which medical officers used gavage at any needful hour of day or night to administer

powdered sulphapyridine. When sulphamerazine was manufactured in Australia it largely replaced sulphathiazole and sulphadiazine, the latter in particular being difficult to obtain freely, and was used in successive doses of 12, 8, 8, 8, and 4 grammes a day, or 9, 6, 4, 4 and 2 grammes a day according to the severity of the infection.

PROPHYLAXIS

Prophylaxis by mass "blanket" dosage was never considered necessary on a large scale. It was sometimes used for limited groups, in order to eliminate carriers. An historically interesting example of the treatment of carriers with sulphapyridine was recorded by Meehan and Merrillees. Meningitis had occurred among 300 children in a foundling hospital in Melbourne, 30 cases appearing over the period November 1937-March 1939. Seventy-five carriers were found among limited groups of the children, who lived in separated age groups. One gramme of sulphapyridine daily for five days per 14 lbs of body weight was found to be well tolerated, and the carriers dropped in number to three. No cases occurred during the following year, up to the time of the report. This appears to be the first published account of mass dosage of carriers to stop an epidemic of cerebro-spinal meningitis.[1]

After penicillin was introduced the therapy of meningitis was still further improved, and sulphonamide-resistant strains could be successfully countered. There was also the advantage of intrathecal treatment by penicillin, though local irritation occurred at times. With full supplies of powerful diffusible sulphonamides and penicillin available, only the severe fulminant septicaemic types offered a very bad prognosis. As Cairns and his co-workers showed, local intracranial abscess formation was still a possible sequel of severely suppurative meningeal infections, a complication demanding full neurosurgical cooperation.

SEQUELS

The sequels of cerebro-spinal meningitis cannot be ignored. Extremes of opinion have attributed these on the one hand to actual irreversible damage to the central nervous system, and on the other hand to neurosis due to bad handling during the illness and the convalescent period. There is surely no doubt that neither of these views completely represents the position. There is no question that organic damage can occur. In a few instances organic palsies occurred in the series studied here, involving the facial muscles, *serratus magnus,* and muscles of the buttock and leg, though it is not certain that in every case such palsies were due to meningitis. Usually, however, no organic lesion could be discovered. The most frequent sequels were backache, headache, giddiness, loss of concentration, and sensitiveness to glare. A complaint that effort, either physical or mental, increased the headache was common. Insomnia and poor

[1] This was drawn to my attention by Professor Loeb's staff in the Medical Centre, Presbyterian Hospital, New York, U.S.A.

resistance to fatigue were also frequent complaints. The personality of some patients during convalescence was found to be of the poorly integrated type, but it is not certain that this was not part of the man's original make-up. Occasional patients were of frankly hysterical or neurasthenic types. There appeared to be some relation between the severity of the attack and the frequency of these sequels. The duration of coma seemed to be significant also, and it seems reasonable to regard this as some index of the severity of disturbance of the central nervous system. These factors were apparently of greater importance than the length of the illness.

On the whole the parallel with patients who have had a closed head injury is striking. Cairns and his associates have shown how important the handling of these men is. The same applies here. There can be little doubt that confidence of the man in his power to recover with a nervous system equal to reasonable demands is an important factor in rehabilitation. There arrives a time in the convalescence of such men when a decision must be made as to what environment is best for them and what type of activity. This decision should be individual, giving men who have been severely ill time to recover, but not allowing them to drift without confidence or incentive. The label of the medical board, officially not disclosed to the men, but almost invariably known to them, does not always give reassurance. Probably the total invalidity due to cerebro-spinal meningitis is not great in the Australian armed forces in this war, but it should be capable of further reduction.

APPENDIX

Instructions—Cerebro-spinal Meningitis

The following is a consolidation of instructions which have been issued in relation to the control of C.S.M. and which should be strictly observed.

In connection with the occurrence of cases of C.S.M. in camps the attention of all Medical Officers should be drawn to Medical Memorandum No. 1 C.S.M. Addendum No. 1 to Manual of Injuries and Diseases of the War notified in the A.A.O. March 1940. A copy of Medical Memorandum No. 1 should be in the hands of the Medical Officer in all camps.

The principles indicated in Medical Memorandum No. 1 should be enforced in dealing with C.S.M. Briefly the following procedure should be adopted:—

A. When a case of C.S.M. occurs in camp.

(1) The patient should be isolated and treatment with sulphapyridine or sulphathiazol in full dosage should be commenced at once. Naso-pharyngeal swabs should be taken.
(2) The patient should be isolated immediately.
(3) He should be removed with the least possible delay to the nearest hospital selected for treatment of these cases.
(4) A full statement of diagnostic action taken, and of treatment given including the dosage administered must be sent to the hospital with the patient.
(5) As administration of sulphonamide affects the subsequent determination or confirmation of diagnosis by bacteriological methods, lumbar puncture and examination of cerebro-spinal fluid for diagnostic purposes should, whenever practicable, be performed before chemotherapy has rendered bacteriological diagnosis difficult or impossible. This should be done only where adequate experience and facilities for this purpose exist at the camp hospital. Treatment

should not be delayed for this purpose, nor should removal of the patient to the special hospital be deferred.

(6) Immediate steps should be taken to confirm diagnosis by bacteriological methods. Every facility and assistance must be given to the pathologist for this purpose.

(7) The close contacts of the case should be put under observation, but need not be isolated. Close contacts are those who occupy beds immediately adjacent to the patient, and any other persons judged by the medical officer to have had a specially close or prolonged contact. At the discretion of the D.D.M.S. or S.M.O. naso-pharyngeal swabs may be taken from close contacts and examined if facilities for the efficient performance of this work are available.

Routine swabbing for detection of carriers serves no useful purpose and should not be carried out.

(8) If any close contact develops catarrhal or other signs or symptoms suspicious of meningococcal infection, he should be isolated, and treatment with sulphapyridine commenced without awaiting result of naso-pharyngeal swab examination.

(9) Constant vigilance should be maintained in the unit and in the camp generally in order to detect clinically suspicious cases at the earliest possible moment. Men suffering from catarrh should be especially watched.

(10) Overcrowding in camp must be eliminated. Instructions for avoidance of overcrowding must be scrupulously enforced. In any rearrangement of accommodation to overcome overcrowding, opportunity should be taken to separate, where this is practicable, men suffering from catarrh, especially if severe and associated with coughing, from the others.

(11) Strict attention must be paid to ventilation in the sleeping and other quarters, and to prevent overcrowding in recreation rooms and canteens, etc.

(12) The following action should be taken in the tent or hut in which the case of C.S.M. has occurred:—

(a) Floor boards, ground and inside of the tent should be exposed to direct sunlight.

(b) The floor of the hut should be washed with disinfectant solution, and the hut thrown open to free air circulation.

(c) Bedding and personal belongings of the patient should be disinfected.

(13) Leave from the camp need not be interfered with, except that close contacts under observation should not be given leave until the period of observation has expired.

(14) Visitors need not be debarred from the camp, but must have contact with the troops only in the open air.

(15) Lectures to troops should be arranged, and the men instructed in personal hygiene in relation to droplet infection, and in the methods by which the disease may spread.

Sufferers from colds and "catarrh" should be encouraged to report for treatment.

B. If cases of C.S.M. continued to occur in a camp, thus indicating the presence of camp infection, all the above measures should be continued, in addition:—

(16) Regular daily medical inspection should be arranged.

(17) Entry of recruits, or troops from other camps, should be reduced to a minimum and carefully safeguarded. Movements should be carried out gradually and not on a large scale. (Recruits should be received into a separate portion of the camp.)

(18) Transfer of troops from the infected camp to any other camp should, as far as practicable, be avoided. When it cannot be avoided, it should be carried out under carefully conditioned precautions in order to reduce contact and overcrowding.



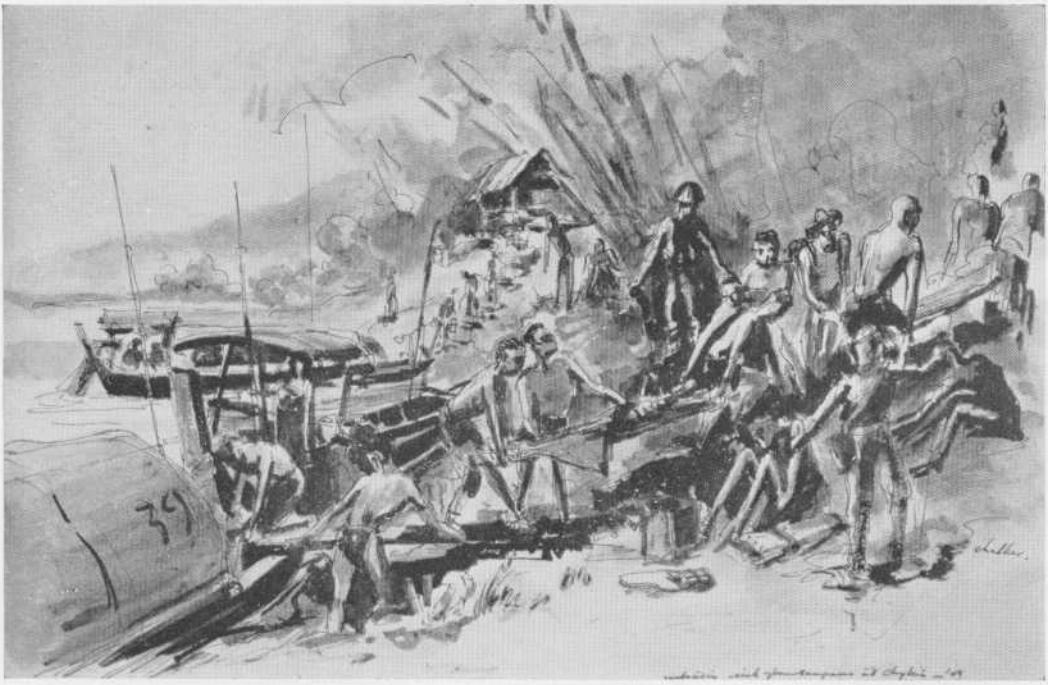
(Australian War Memorial)

Wounded arrive in Ramu Valley by jeep ambulance.



(Australian War Memorial)

Evacuation by air in New Guinea.



(Drawn by J. Chalker)

Unloading sick from sampans at Chungkai.

(19) Troops in the camp should not be worked to the point of fatigue. Action should be taken to ease training until the manifestations have subsided.

(20) Strict care should be exercised in relation to permission for visitors to enter camp. Entry of children to the camp should be forbidden.

(21) Leave of troops from the camp should be controlled, and troops going on leave should receive special instructions as to personal hygiene in relation to the possibility of conveying droplet infection while on leave.

Notification.

(22) The medical officer must immediately report any case or suspected case occurring in camp or elsewhere to the S.M.O., who will immediately notify the D.D.M.S.

(23) The D.D.M.S. should at once notify the D.G.M.S. by wire or other most rapid method, of every case or suspected case notified to him. This notification should include the name, unit, camp, date and place of isolation, and date of onset and whether a member of the Permanent Forces, Garrison Battalion, A.I.F., Militia, or Universal Service Personnel.

(24) The D.D.M.S. should, as soon as practicable, confirm the telegraphic notification to the D.G.M.S., by mail (in the case of Northern and Western Command and the 6th, 7th and 8th M.D.'s by air mail), giving in addition the following details:—

Regimental number (indicating whether A.I.F., Militia, etc.).

Age.

Details regarding action to clinch diagnosis.

The result of bacteriological investigation (followed by a copy of the pathological report as soon as available).

Brief statement of treatment employed with progress of case.

Length of time under military training (that is, period since joining camp from civil life).

Patient's movements within the few days prior to onset, together with any ascertainable facts of epidemiological importance which might indicate whether infection was contracted in camp or outside.

(25) The D.D.M.S. should advise District Records Office immediately of all cases of C.S.M. occurring in military forces, whether Permanent Forces, Garrison Battalion, A.I.F., Militia or Universal Service Personnel.

(26) The D.D.M.S. should notify the State Department of Health of each case, and maintain touch with that Department for consultation, and for mutual exchange of information regarding cases of C.S.M. and close contacts, which may be of value in relation to control measures.

12.9.41.

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CHAPTER 16

DIPHTHERIA

DIPHTHERIA is always a potential enemy. At the beginning of the war it was not thought necessary to immunise members of the fighting Services against diphtheria, but with the qualification that this might be necessary in special circumstances.

In 1940, 39 cases were reported from the army in training in Australia (a rate of 2.78 per 1,000), but during the same year in the Middle East the A.I.F. had 122 cases with an incidence rate of 8.56 per 1,000. This rate was far from negligible, though not a source of anxiety, since most of the infections arose in circumscribed areas, where prompt recognition and observation of contacts controlled these outbreaks. In September 1940 Brigadier Burston convened a special committee to investigate the incidence of diphtheria in the A.I.F. camps in Palestine. Cases had been recognised during the summer months, especially in two battalions. Investigation was made of contacts by swabbing their throats, and individuals suspected of being carriers were isolated: following this action the disease died down in the two camps concerned. Investigation of one area revealed seven almost symptomless cases. The committee's investigations were reinforced by a conference of consultants of both British and Australian forces, and it was thought that although a run of infections had occurred in the 17th Australian Brigade, there was no risk of a large outbreak. Some overcrowding had occurred in the camps, but the sickness rate was not increasing. Schick testing and immunisation were therefore not considered necessary, provided enough toxin-antitoxin mixture was held to immunise the brigade if required. There was no need to interfere with troop movements.

Cutaneous diphtheria was recognised as a possible disseminator of infection, and its presence in the common indolent sores was always possible, so that vigilance was necessary. In point of fact it was not a significant factor in the septic sores seen in 1940-1941 in the Middle East.

In November cases of pharyngeal diphtheria were still occurring in the 17th Brigade, in another battalion. Two carriers were found and the rate declined. During 1941 the case rate for the A.I.F. fell, being 4.11 per 1,000 for the year, though the total number was considerable, 314. In Australia the rate was lower, the total number of cases reported being 94. Several deaths occurred in the Middle East, one of those who died was a patient who had had exfoliative dermatitis due to arsenic used in treating syphilis, one was a man who was convalescing from severe Shiga dysentery, and one death occurred from sudden anaphylaxis while antitoxin was being administered. During the summer of 1941, while working in Syria, the 1st Australian Mobile Bacteriological Laboratory examined 644 throat swabs in three months; from 48 of these a diphtheria-like organism was grown, but no virulence tests were carried out. Nineteen

swabbings of wounds showed 7 cultures of diphtheroids; no evidence of virulence was found in these. During routine swabbings of contacts in Syria some carriers were discovered among cooks.

A long stay in hospital was often found necessary to render patients free of infection: the average time in one hospital was thirty-five days. Tonsillectomy was required occasionally.

In the latter part of 1941 cutaneous diphtheria was more commonly seen, and the ulcers, painful and with sloughy bases, usually healed promptly with serum. Two more deaths occurred from cardiac failure. Five members of the staff of the 2/3rd Australian Casualty Clearing Station in Beirut contracted diphtheria, and initial steps were taken to carry out Schick tests and if necessary to immunise members of the staff. However, the unit returned to Australia before any material for the tests was supplied.

Early in 1942 at a conference at Cairo of physicians in the Middle East forces the subject was discussed. It was advised that antitoxin should be given only after a swabbing was taken, and then only if toxaemia was present, or if a culture was obtained. Attention was drawn to the value of analgesia and anaesthesia round the skin lesion in cutaneous diphtheria. Subsequent observation showed the value of this clinical sign. The lesions themselves were frequently painful and tender, contrasting with the surrounding analgesic zone, which was frequently pigmented in chronic infections. The sloughs in the ulcer occasionally took the form of extensive membrane, and the sero-sanguineous discharge characteristically coloured the dressings pink. These features were of real diagnostic value. Some British physicians also pointed out that patients with cutaneous infections sometimes also harboured the organisms in their throats. The possible importance of this in spreading the infection was noted.

Similar discussions were held at a clinical meeting at an A.I.F. hospital in Palestine. Medical officers found that in spite of large doses of antitoxin ulcers apparently infected with diphtheria did not always heal, and the validity of the clinical and bacteriological diagnosis was in doubt. A proposal was made that in view of the relative scarcity of antitoxin it should be used only for skin lesions from which true diphtheria bacilli were isolated, lesions with membrane clinically resembling diphtheria, and chronic ulcers failing to heal in which diphtheria-like organisms were present.

Twelve cases of cutaneous diphtheria were described at this time by Niesche, who obtained satisfactory results with sulphanilamide powder and antitoxin. Most of the types seen were of the ulcerous variety, but the necessity of looking for diphtheria in even eczematous or bullous lesions in the nose and ear and elsewhere was recognised. Two cases of diphtheria of the penis were seen in Palestine: one man died from respiratory failure.

In the later years of the war less trouble was given by diphtheria. In 1943, 175 cases were reported among the growing number of servicemen in Australia, an incidence rate of 0.46 per 1,000, but in the island cam-

paigns the disease was rare. A special reason for care in investigation was recognised at this time, owing to the possibility of diphtheria being a cause of the localised types of neuronitis seen not infrequently throughout the war. This question is discussed in the section on nervous diseases. Routine swabbings were often carried out on men suffering from these palsies, but no evidence was obtained that diphtheria was a significant cause.

Sequels were occasionally seen. Missed infections supplied some of these in which polyneuritis occurred after a mild throat lesion believed at the time to be non-diphtheritic. In a couple of severe infections widespread and prolonged paralysis occurred, in spite of the use of large doses of antitoxin.

In the 8th Division diphtheria took considerable toll. At the time of the compulsory concentration by the Japanese of the forces in Selarang 28 cases were recognised among the A.I.F., and the incidence was reported as being much higher in the British troops. Investigation showed a high carrier rate. In 1943 diphtheria was prevalent in the Changi area, and at Australian hospitals on Singapore Island cutaneous infections were common, especially in association with scrotal dermatitis. Two men died out of 103 with diphtheria in the first year. Antitoxin was scarce and it was impossible to use it for every patient. It is hardly surprising that under these conditions peripheral neuritis was not infrequent, though no cardiac complications were seen other than occasional tachycardia, constant or paroxysmal. Isolation of carriers was at this time impossible to carry out, but in spite of these discouraging circumstances special bacteriological work was undertaken. Cultures were made on direct smears of a coagulated egg medium prepared in the camp area. At a later period as many as 70 per day were examined, and from the diphtheria organisms thus isolated toxin was made with a view to preparing toxoid for immunisation. This measure was not needed, but the resource shown in the work was highly commendable, especially as the laboratory facilities were almost nil and most of the work was perforce carried out in the open.

During the period of captivity diphtheria waxed and waned among the Australian forces. The most troublesome period on Singapore Island was from July to December 1942, when a special wing was necessary for A.I.F. patients. Of 93 treated here 64 had proven diphtheria; 14 of these had nasal infections, but only 4 had neuritic complications.

Cutaneous infection was common throughout the whole period; in the first twelve months the percentage rose as high as eighty-five. In Changi diphtheria was only occasionally seen in 1944, but in 1945 more faucial infections again appeared, and a considerable crop of skin lesions. Isolated outbreaks occurred in some of the camps, as in Thanbyuzayat. In many of these places conditions were very bad, and with no facilities for investigation and often no means of treatment the problem was at times of considerable significance. At the base of Kanchanburi diphtheria was rife for a time, and as the Japanese issued antitoxin sparingly, the serum of convalescents was used with good results.

Reviewing the 1939-1945 war period diphtheria only caused real anxiety during the outbreaks in the Middle East and among the 8th Division, where it was but one of many much more serious worries. The highest rate per 1,000 average yearly strength of the army was in the Middle East in 1940, when it rose to 8.56. In 1941 and 1942 it fell to 4.11 and 2.74. In Australia and the South-West Pacific Area the rates were much lower, never exceeded 0.60 per 1,000, and were usually below 0.20. However, in these three areas alone some 1,200 men were rendered ineffective for some weeks, so the incidence was not negligible. The question of immunisation, raised several times, was never given a categorical answer, though no action was taken. It is doubtful if the mass immunisation of a force is necessary, but the occurrence of local outbreaks is a good reason for the performance of Schick tests on those exposed to risk, and for further action should the need arise. It is to be hoped that the growing acceptance of immunisation against diphtheria by the public will still further lower its incidence.

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CHAPTER 17

EPIDEMIC PLEURODYNIA (BORNHOLM DISEASE)

MANY studies of epidemic pleurodynia have been made in the literature. One outbreak was reported in the Australian Army, and it is not unlikely that other cases occurred.

During the first large epidemic of sandfly fever in the Middle East in 1940, similarity was noted between an oppressive pain in the chest common in that series and the constrictive type of pain often complained of in the Bornholm disease. In this observation was an oblique suggestion that epidemic pleurodynia might prove to be a variant of the sandfly-dengue group. Megaw has suggested that this disease may be spread by an insect vector, but no relevant information on this is available so far.

In 1944 when Andrew described the features of an epidemic of Bornholm disease in troops in North Queensland speculation was raised whether the disease, certainly an infection, might not be a member of the dengue-sandfly fever group. It might be further pointed out that the pain in pleurodynia occasionally spreads to the neck, at first sight suggesting a condition of meningismus. A parallel between epidemics of pleurodynia and poliomyelitis has also been suggested by some writers on epidemiological grounds. This too appears to be surmise only.[1]

This outbreak in North Queensland affected 35 men who were studied in hospital. Most of them were under 25 years of age (24 out of 25). The pain which is the chief feature of the disease extended from the upper abdomen into the lower parts of the chest. When unilateral it was more often on the right side, but bilateral and central pain was common. It was a constant pain, accentuated by all special respiratory activity. Half the patients had a chill or mild rigor. A few had a dry cough. A pleural rub was heard in some, but X-ray examination revealed no abnormality in the lungs or diaphragm. No blood changes were found, and experiments with mice into which the blood was injected were inconclusive. A good recovery was made by all patients, the only residual symptoms being tenderness which disappeared in a week. No complications were observed such as orchitis which is stated to occur occasionally in some epidemics. No evidence of food infection or the existence of a vector was adduced from this outbreak, nor was there anything found to suggest a possible relationship with another disease.

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[1] Later work indicates that the Bornholm disease may be of epidemiological importance in the study of poliomyelitis.

CHAPTER 18

INFECTIOUS MONONUCLEOSIS

INFECTIOUS mononucleosis or glandular fever occurred sporadically in all the Services, and sometimes offered a characteristic, but not always simple diagnostic problem. At one time it was not uncommon in ships of the Royal Australian Navy; as a result of this a considerable series of cases was studied in a Royal Australian Naval Hospital in Sydney. This series was not part of a shore epidemic, but resulted from the close contact of men in mess decks. It never attained serious proportions. In one destroyer, for example, three new cases appeared fourteen days after departure from Sydney. A considerable number of men were at first thought to have streptococcal tonsillitis or an infection by Vincent's organisms, which latter was not rare in the Royal Australian Navy. A thick white membrane on one or both of the tonsils was a not infrequent finding. Lieut-Commander J. K. Maddox drew attention to the true nature of this epidemic and Technical Instruction No. 16 was issued by the Director of Naval Medical Services. More than one patient was suspected of having typhoid fever, by reason of continued pyrexia and the predominance of abdominal symptoms. Abdominal pain was probably related to involvement of the mesenteric glands. The diagnostic value of inguinal adenitis was pointed out in the naval instruction. Although this may be due to other causes, such as superficial infections on the lower limbs, it is a less frequent form of glandular swelling than that of the cervical lymph nodes, and therefore a more provocative sign.

Jaundice was seldom seen. Involvement of the meninges occurred rarely, but was not serious. Neck rigidity might be present without any abnormality in the cerebro-spinal fluid, or cells might appear including polymorphonuclear leucocytes, but these signs settled down quickly without further trouble. Photophobia was occasionally present. A rash occurred only infrequently, but then tended to cause confusion with other exanthems. The blood picture was diagnostic when the characteristic abnormal mononuclear cells appeared, both qualitative and quantitative changes in the white blood cells being significant. The lag in time before this reaction occurred was apt to be misleading.

The Paul-Bunnell test for heterophile antibodies was not found very useful under service conditions because of the lack of facilities except in settled areas, the frequent delay in the appearance of a reaction, and the fact that it was sometimes absent. Comparison of the results of repeated tests gave more valuable information than the exact figures.

The total number of cases of mononucleosis recognised in the Services was small. The greatest number in the army in any year of the war was recorded in 1945, a total of 64, with an incidence of 0.324 per 1,000. Figures for other years show a tenth or less of this incidence rate; this might be due to a small epidemic during this period, but it is probable

also that the disease was sometimes overlooked until attention was drawn to it. It is known that either the virus is of low infectivity or the pre-existing immunity of most people is high, but it is rather surprising that more outbreaks did not occur under conditions apparently favourable for transmission.

Under this heading may be mentioned an infection which was observed on the Atherton Tableland in Queensland. A number of men were admitted to hospital with a mild illness, often unassociated with fever. They complained of headache and malaise, slight shivering and sore throat. Enlargement of the cervical, axillary and inguinal glands was observed; they were not tender and sometimes the patients did not notice them. The spleen and liver were only occasionally palpable. A distinct dark red macular rash was distributed over the trunk, arms and legs. The white blood cells were 7,000 to 10,000 per cubic millimetre in number, with 41 to 61 per cent lymphocytes. Monocytes were normal as a rule. In one instance they formed 21 per cent of the total white cells, and 20 per cent of the lymphocytes were abnormal also. In no instance could a reaction to the Kline, Weil-Felix or Paul-Bunnell tests be demonstrated.

Biopsy of the glands, checked by controls, showed non-specific reactive changes, though islands of reticular cells in germinal centres showed very active hyperplasia. Numerous mitoses were seen and granules suggesting inclusion bodies were noted in some unusual looking cells. The biopsy from one man showed also eosinophile cells, and as he had intermittent pyrexia, he may have had Hodgkin's disease. The nature of this infection was in doubt, but it seems closely allied to infective mononucleosis.

In the treatment of the demonstrated cases, sulphathiazole was used in one naval hospital with apparent abatement of the febrile stage. One feature noticed was the prolonged weakness which followed the infection. Relapses were occasionally seen. Considerable loss of weight was quite common.

The limited experience with this disease during the war emphasises the frequent difficulty of diagnosis and the confusing nature of the clinical variations. This was evident in the number of *formes frustes* seen in Canonbury Naval Hospital in Sydney. The diagnostic difficulties were further emphasised by the number of possible causes of glandular enlargement in men exposed to service conditions in a tropical area.

Further brief reference is made to this in the section dealing with pyrexia of unknown origin.

REFERENCE

D.N.M.S., R.A.N., *Tech. Instr.*, No. 16.

CHAPTER 19

PYREXIA OF UNKNOWN ORIGIN

THE term pyrexia of unknown origin has earned some notoriety as a military diagnosis, but its use is really a recognition of the difficulty of classifying fevers by aetiology. Graham Butler said: "P.U.O. is a tribute to reality". Sometimes this diagnosis was used because patients were transferred from forward medical units before thorough clinical observation could be made and when opportunities and facilities for investigations were lacking. Even in fully equipped hospitals the diagnostic problem could not always be solved, as febrile diseases cannot always be distinguished by specific tests.

The differentiation of pyrexias varied in difficulty with the locality. Tropical areas, with their wealth of pathological possibilities, held many problems. North Queensland, where so many troops were stationed from time to time has long been recognised as possessing a wide variety of infective agents whose invasion of man presents many diagnostic puzzles.

No attempt will be made here to present a complete list of possible causes of fever, but all the diseases mentioned have at times caused perplexity among service medical officers during the war period. It is useful, especially under service conditions, to regard a patient with a febrile disease as suffering from a short-term fever, or from a mild variant or *forme fruste* of a disease not usually of short duration, or as being in the early stages of a more severe continued fever.

A. SHORT-TERM FEVERS

Examples are as follows:—

(I) SANDFLY FEVER

(II) DENGUE FEVER

These are well-defined diseases though with characteristic variation in the clinical pattern. Owing to the geographical distribution of vectors on the fronts where Australian forces served, the necessity for distinguishing one from the other did not arise.

(III) EPIDEMIC POLYARTHRITIS

This seems to be a variant of dengue, but lack of proof as to the nature of the infective agent and the vector leaves this unproven. Its clinical features are fairly distinctive as described in Chapter 8.

(IV) OTHER DENGUE-LIKE FEVERS

It is probable that the virus of dengue has undergone mutation, causing a number of clinical variants. These variants gave more trouble in diagnosis than any other short-term fever. Many examples in the services could be cited. Brief "three-day" fevers were observed in the Helidon district near Toowoomba in Queensland in 1943, in the naval stations in Darwin and

Moresby, and in the air force station on Goodenough Island. The observed symptoms differed from those seen in other epidemics sufficiently to cause diagnostic doubt, and the vector was not positively ascertained, but there seems little doubt that all belong to the dengue group. In the hospital in Changi on Singapore Island in January 1945, many men were seen with short fevers which might have been due to dengue fever, but with the restricted laboratory facilities no conclusion could be reached. Another series occurred there a month later, which was equally obscure, though a few men at least were thought to have a pyaemic illness.

In America, diseases like Bullis fever, pretibial fever and Colorado tick fever, strongly resemble dengue fever. Pretibial fever, if proved to be borne by mosquitoes, would certainly be classed with the dengue group, but if, like Colorado fever, carried by ticks, it would be separately classified. Bullis fever, rickettsial in origin, and borne by ticks, would more naturally suggest analogy with Q fever. There is no proof that all these infections have counterparts in Australia or the South-West Pacific Area, but it would be curious indeed if the full story of insect vectors here has been told. Reference has been made elsewhere to a febrile epidemic at Salamaua and Lae. The prevalence of *Culicoides* here inspired a suggestion that this might be a vector, but this was mere speculation and the disease was regarded as of the dengue family.

(v) EPIDEMIC PLEURODYNIA (BORNHOLM DISEASE)

Though the symptoms of this disease are distinctive, milder attacks occur; it seems certain that sporadic cases are unrecognised.

(vi) RESPIRATORY DISEASES

These only need mention, for the local symptoms should indicate their true nature; but the occurrence of pharyngitis in the early stages of other febrile illnesses may be confusing.

B. MILD TYPES OF OTHER INFECTIONS

(i) TICK-BORNE TYPHUS

This has been mentioned in the section on typhus fever. It is by nature briefer and milder than other varieties of typhus, and produces different agglutination reactions. Without a consciousness of its possible presence in an area even a careful observer could easily overlook it.

(ii) Q FEVER

This infection was recognised before the war as certainly more widely spread than its original discovery in Queensland suggested, as this strain of *rickettsia* was found also in N. America. Its importance in Italy, where New Zealand medical officers studied its effects on their troops, showed it to have a world distribution. No proof exists that it was of significance among Australian troops though rare instances occurred, but as a member of the so-called "atypical" groups of pneumonic infection, it merits consideration.

(III) LEPTOSPIROSIS

The existence of this disease has been well known in Queensland since 1933, and by 1939 five separate strains of the *Leptospira* were known in Australia, including the classical *icterohaemorrhagica*. Mild infections are known to occur, and, as world wide experience has shown, jaundice is not by any means a constant sign. Reference has been made to a series of men with infective hepatitis who were at first thought to have spirochaetal jaundice. It would be strange if infections of this kind had not occurred among the military concentrations in Queensland, but very few seem to have been recognised. One mild infection was proven at the 2/2nd A.G.H. on the Atherton Tableland. The temperature subsided in four days, and the serum agglutinated *Leptospira Australis* A to 1 in 100.

(IV) INFECTIOUS MONONUCLEOSIS

This has been briefly described in Chapter 18. It is possible that cases were overlooked, not only of the anginous form, in which a confusing exudate on the pharynx was apt to divert attention from the systemic condition, but also of the type in which swelling of the glands was a conspicuous sign. In reports from the 2/2nd A.G.H. in Queensland, Andrew, Hertzberg and Ferris drew attention to the number of mild febrile states seen there in which glandular swelling was noted. The cause of some of these was not elucidated; it might include mononucleosis, varieties of typhus or other rickettsial diseases, or virus infections related to dengue. The relation of glandular swellings to exanthemata like rubella may also be recalled.

(V) CHORIOMENINGITIS

The virus of benign choriomeningitis may occasionally be responsible for mild aberrant infections, and mice can carry the infective agent, thereby posing an epidemiological problem which might not be settled unless obvious meningeal involvement occurred.

(VI) INFECTIVE HEPATITIS

The onset of hepatitis of the epidemic type may be misleading especially if acutely febrile, and if jaundice does not appear, a diagnosis may be made of sandfly or dengue, or other short-term fever if these diseases are endemic in the area.

(VII) RELAPSING FEVER

Though usually distinctive, this spirochaetal infection may show only mild manifestations in some of the recurring attacks. The history and the appearance of neurological complications should make the position clear.

C. CONTINUED FEVERS

In the early stages, some continued fevers are not distinctive and in the middle of epidemics this is important, as missing the ideal time for certain investigations like blood culture may make the diagnosis more difficult.

(I) TYPHOID AND PARATYPHOID FEVERS

Typhoid fever may appear even in an ambulant form. Even mass inoculation does not preclude its occurrence. In tropical areas and in other circumstances where diarrhoeal diseases are common, the presence of abdominal disturbance may obscure the true cause.

(II) SALMONELLA INFECTIONS

In addition to the more severe forms described elsewhere, mild attacks may occur; some of these were found deceptive, especially in areas where bacteriological investigation was difficult. The presence of brief illnesses and continued fevers in the same outbreaks may be confusing.

(III) BRUCELLOSIS

A brief description of this has been given in Chapter 14. It is of course soon obvious that the patient has a continued fever, but careful clinical examination is important as serological confirmation is not always simply attained.

(IV) OTHER SEPTICAEMIC ILLNESSES

Some of these may be very difficult of recognition, such as meningococcaemia, dealt with elsewhere. Therapeutic evidence is sometimes useful. Infective endocarditis may also be confusing.

(V) TYPHUS

Typhus of the mite-borne or flea-borne type was not always diagnosed immediately in the field, but usually revealed itself soon as a continued fever of a distinctive pattern.

(VI) AMOEBIASIS

Amoebic infection, particularly of the hepatic type, often proved most obscure. Even repeated stool examination sometimes failed to demonstrate the amoeba, and unless the valuable method of therapeutic trial was used on suspicion, later events occasionally disconcerted the clinical observer.

(VII) TUBERCULOSIS

Because it was not always thought of and because it was not obvious tuberculosis was another occasional deceiver.

(VIII) MALARIA

It may seem superfluous to mention malaria, but the *falciparum* type when occurring in a non-endemic area has proved confusing.

(IX) RETICULOSES

The Pel Ebstein type of Hodgkin's reticulosis was a rare cause of fever.

As an illustration of the types of special investigation which may be needed to elucidate pyrexial illnesses, the following may be given. It was used at the 2/2nd A.G.H. when stationed on the Atherton Tableland,

North Queensland, the patients being men who had usually been in the tropical islands to the north, and thus subjected to the endemic infections there as well as others found in the northern parts of Australia. Investigations carried out were:—

During 1st week	Examination of blood smears for malarial parasites. White blood cell count. Blood culture. Blood culture in Fletcher's medium. Animal inoculations.
During 2nd week	White blood cell count. Culture of stool. Agglutination tests: Brucella, Weil-Felix, Paul-Bunnell. Dark ground examination of urine.
During 3rd week	Agglutination repeated. Leptospira agglutination. Q fever agglutination.

To these methods were added others on occasion. Gland biopsy was occasionally used, as in one series at the 2/2nd A.G.H., in which a group of men had a mild slightly febrile disease of undetermined type. Biopsy showed hyperplasia of reticulum cells, and other peculiar cells were seen containing material like inclusion bodies.

It should be clearly realised that pyrexia of undetermined origin is a regional problem, whose solution may best be effected by close clinical survey, appropriate laboratory investigations and the study of its epidemiological features. Even after the most careful examination there will be an obscure residuum.

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CHAPTER 20

RESPIRATORY DISEASES

RESPIRATORY diseases have not been of great importance in Australian forces actually in the field during the war. In camps and training areas respiratory epidemics have been important wasters of men, and have carried with them the usual complications, sinusitis and middle ear inflammations, and to a lesser extent pneumonia.

UPPER RESPIRATORY TRACT INFECTIONS

This comprehensive title familiarly abbreviated to "U.R.T.I.", avoids the aetiological problem which can be solved only by full expert investigations into the bacterial and viral agents responsible. During the first winter of the war widespread outbreaks of respiratory disease attacked the training camps. These were accentuated somewhat by the unsatisfactory conditions prevailing in some of these camps, where building and the hygienic accessories of plumbing and hot water had not yet caught up with military requirements. One of the medical anxieties of a war, particularly in its early stages, is to prevent the spread of communicable disease in surroundings that are often unsatisfactory from the standpoint of hygiene. The care of men slightly ill with such complaints is often a difficult matter, as each man acts as a nucleus of infection.

We are, at present, however, more concerned with the technical aspects of these infections, which not only affected men under training, but were epidemic in the civilian population too. Methods of prevention are closely concerned with the military aspects of quartering and facilities for isolation and treatment, and are dealt with in Volume II. It may be remarked here that no such measures can be complete or successful without taking into account modern work on dust and infection in hospitals. The oiling of floors and blankets, and the efficient sunning and airing of bedding, with the avoidance of undue agitation in closed spaces, should be considered in model routine orders for camps. There can be little question that early morning bedmaking activities can become what would be aptly described as a "cross-infection parade".

Apart from these important problems of prevention the most significant medical questions were the incidence of severe accompanying pulmonary disease, such as lobar or broncho-pneumonia, and the possibility of an epidemic of severe influenza. Fortunately during the epidemic of respiratory tract infections in 1940 pneumonia seldom occurred, though many men were quite ill with symptoms and signs of an intense tracheobronchitis.

In all training areas of Australia, particularly during the cold weather there were outbreaks of these respiratory diseases, often complicated by the co-existence of diseases like measles, also spread by droplet infection. All armed Services were affected. The Royal Australian Navy experienced not only a high incidence of common colds and similar epidemics in

training establishments but also in ships, where the closed nature of the community enhanced the risk of infection. H.M.A.S. *Cerberus,* chief shore training establishment, lost nearly 6,000 man-days in the war period 1939-1941. There is some interest in studying graphs of the rate of incidence of these respiratory infections; in some States sharp short rises with high peaks were seen, with a base of some three to four weeks. This was particularly noticeable in circumscribed areas such as Tasmania. Though there is a tendency to think that these epidemics are chiefly troublesome in the early days of the war, the lines of communication areas were plagued with them right through. In 1944, for instance, combined figures for "U.R.T.I." pneumonia and influenza showed a considerable incidence. The months of greatest illness were not the same in all areas: in N.S.W., for example, a maximum of 12 per 1,000 per week was reached in April and May, in Queensland, 11 per 1,000 in May, and in Western Australia 10 per 1,000 in May and June; in Northern Territory and South Australia the incidence was very low, not over 3 per 1,000. In New Guinea during this year the rate rose slightly in April and May but remained consistently low, not over 4 per 1,000. In general, respiratory disease was uncommon in the tropical areas.

A certain amount of mild respiratory disease, apart from pneumonia, occurred in the Middle East. Some of this appeared in the winter months: at other times it was noticed in Egypt after men had returned from leave in Palestine. Considerable numbers of such infections were common on sea transports from Australia, especially the large ships which were not adapted for large numbers of men travelling through the tropics. The significance of these outbreaks in relation to inflammatory affections of the sinuses and middle ear has been noted in Chapter 56. Occasional outbreaks of acute streptococcal infection occurred, for instance, in the winter of 1942 when one death occurred in a field ambulance in Syria, and other virulent attacks were seen, usually with considerable glandular swelling in the throat. Care was taken in New Guinea to maintain a certain barrier between white troops and natives to minimise the passage of infections. This was particularly so with respiratory disease, but the segregation of natives in compounds for the sake of malarial control, the care given by Angau medical services, and the good standard of native hospitals prevented any trouble of this kind.

Occasional outbreaks occurred in advanced base areas, such as Moresby; tonsillitis appeared in Tarakan during the Borneo operations; in Bougainville in the Solomons this and other manifestations of upper tract infections were common in 1945. In Finschhafen in New Guinea too, coryzal illness appeared in the spring of 1944, with many cases of bronchitis. These infections were undoubtedly brought from the mainland, where there were always foci, regardless of season. On the Atherton Tableland, for example, respiratory disease was not uncommon, and even in tropical climates like Townsville occasional outbreaks occurred. It is interesting that during the Owen Stanley campaign in 1942, in spite of exposure to

rapid changes of climate and privations of comfort, sleep and food, the men did not suffer from respiratory disease.

The clinical and bacteriological findings varied from season to season and from place to place. Mixed bacterial infections were not uncommon, and at times these produced severe complications. An instance of this was seen at Bathurst camp in the winter of 1942. Respiratory tract infections such as the "common cold" were widespread at the time, and measles was also prevalent. A number of unusually severe broncho-pneumonias occurred, with several deaths. The sputum contained haemolytic and non-haemolytic streptococci, and *Staphylococcus aureus*. The most severe infections were found in men who, during the pre-eruptive stage of measles, had been exposed to other catarrhal cross-infections. Early isolation was not always easy in a large training area in which there was some shortage of medical officers, but when this was achieved the pneumonic complications ceased.

INFLUENZA

A question which caused considerable anxiety in medical circles in Australia during the early days of the war was whether there would be a visitation of pandemic influenza. Indeed throughout the war years this anxiety persisted, as there had not been a pandemic of influenza since 1918-1919. Such global outbreaks have occurred at intervals before, but one unusual feature of this 1918-1919 epidemic marked it on the calendar with special emphasis. This was the high mortality it caused in young adults. Indeed there was a certain assumption in the minds of many hygienists and epidemiologists that, since the world appeared to be due for another epidemic, one would appear of similar character to that which swept the world after the last war. Prophecies were not fulfilled, but nonetheless the research done during the war years on influenza was most valuable, and had an outbreak occurred at least the community would have been better prepared than previously. Knowledge of influenza has been gathered only of recent years, since virus research has become of sturdy growth, and it is very incomplete yet. The reasons for the appearance of epidemics due to different forms of virus are not clearly understood, nor why the epidemics die down or assume a sporadic character, when there is evidence that there are many people unprotected in the community.

Since 1935 much successful work in the isolation of the influenza virus had been carried out at the Walter and Eliza Hall Institute in Melbourne, and important advances were made in the technique of cultivating it in the chick embryo. By 1940 it was possible to harvest considerable quantities of cultivated virus from the allantoic fluid, by use of the Hirst agglutination method of titration. By these means not only could viruses be isolated, but they could be grown in bulk sufficient to produce vaccines for experimental purposes, and tests for immunity in the blood serum of human subjects could be readily carried out.

In the winter of 1939 Dr F. M. Burnet and his co-workers in Melbourne had duplicated the English experience in finding several types of

influenza virus during an apparently homogeneous epidemic. An outbreak in Europe was then expected to occur, and if immunisation was to be attempted it was obvious that recognition of the viral types was important. In Australia the use of an attenuated living virus was thought to be promising for immunisation, and during 1940-1941 volunteers in Victoria were treated with nasal spray of such a preparation. Antibody titration gave rather uneven results, but Burnet found that persons with very low antibody usually responded to a living virus vaccine with a mild general reaction and a definite rise in antibody. These persons were those who should be most susceptible to the disease.

In Puckapunyal camp in Victoria an epidemic of upper respiratory tract infections broke out in the early winter of 1940. By the beginning of July, 250 men were in hospital each day in the camp area. There were few serious complications, but intense pharyngitis and laryngitis were common. Few cases of pneumonia occurred. Two instances of dendritic ulcer of the cornea were noted, of herpetic origin, and associated with respiratory tract infection. Influenza virus was isolated during this outbreak, and proved by ferret inoculation. For the first time too, direct inoculation of nasal washings into the embryonic amniotic sac was successful. During 1940 there was little true influenza in Melbourne, but several strains of virus were isolated from various sources. The volunteers mentioned above, who were treated with nasal spray of attenuated virus, did not always resist a fully active strain, and it was evident that a less attenuated strain would have to be used to produce effective immunity. One interesting finding in this work was that the "new" influenza "*B*" virus recognised overseas had been causing attacks in Melbourne during the previous two years. As no cross immunity existed between types *A* and *B* both strains would need to be used for a vaccine.

During 1941 no epidemic of virus influenza was recognised, though a respiratory epidemic clinically of influenzal nature occurred during the early summer. Further experiments were carried out on volunteers, all available *A* and *B* types of virus being used. The strains attenuated by 40 to 100 passages in chick embryos were used for immunisation of these volunteers, with the cooperation of Colonel Gordon Shaw, D.D.M.S., Victorian lines of communication area. It was recognised that evaluation of the results would be difficult, owing to the patchy nature of influenza except in widespread epidemics, and the probable lack of adequate controls. There seemed to be reason to hope that immunisation by this method would be at least as effective as the subcutaneous method then being used in America, for which 50 per cent success was claimed.

During 1942 one hundred and twenty volunteers from the army were inoculated with a mixed virus vaccine. An atomiser of the de Vilbiss pattern was used, vaporising 0.2 c.cm. of allantoic fluid. Symptoms were trivial, not more than a mild coryza, and rises of antibody were demonstrated, particularly where its previous level was low. The potential importance of this work was enhanced by the possibility of a pandemic at this time, when the movements of armies and refugee populations ap-

peared to favour its appearance. In the late autumn of 1942 a typical outbreak of influenza occurred in camps in Victoria. Characteristically, cases were recognised in camps separated widely, sometimes by hundreds of miles, within a week of the first demonstrated infection of true influenza. The peak occurred within two or three weeks, the rate per 1,000 men rising from 10 to 100. The clinical characters resembled strongly those of the epidemic in Britain in 1937, and influenza virus *A* was isolated in May and September 1942.

Titrating experiments showed that the initial antibody level was lower in patients than in others who remained well, but a sharp rise was observed during convalescence. Though the incidence of influenzal disease had been lower at this time than at any period since the outbreak of the war, 1,731 cases occurred during the last week in May when this outbreak was at its peak. It was possible to investigate thoroughly only a small group of thirty men, as the resources of the Walter and Eliza Hall Institute were at the time largely occupied by the production of attenuated virus for inoculation. This work, however, led to interesting observations on contrasting features of this influenza virus and of stock strains when inoculated into the amniotic sac of the chick embryo. The strains were found to possess certain "unadapted" characteristics, and thus the O type (original or unadapted) and D type (derivative) were distinguished.

By the time a large-scale immunisation plan could be put into effect this epidemic was well under way, but in one unit of 7,000 to 8,000 men some observations were possible on the results of the experiment. The total figures for respiratory disease for the epidemic period were 6.6 per cent among the unimmunised and 4.4 per cent among the immunised. No difference was apparent among the numbers of men sent to hospital for clinical influenza. Thus no striking results were obtained in this partial experiment. Mawson and Swan in similar work in South Australia found that nasal inoculation did not produce more antibody than subcutaneous injection, but they thought that the acquisition of local resistance would be valuable. Numbers of other technical observations were made in the course of this work which are too detailed for consideration here, as we are concerned rather with the broad picture of the possibilities of influenza among masses of recruits in training camps, and among the civil community.

One local epidemic of a severe and sometimes fatal respiratory epidemic of influenzal character was reported from Niue, in the Tonga Group, in the later part of 1943, but this did not spread further in the Pacific.

During 1944 no epidemic influenza occurred in Australia, and neither *A* nor *B* type of virus was isolated from patients with respiratory disease. Records of soldiers immunised against influenza showed no difference in the incidence of respiratory infections. Some useful research work was carried out at the Walter and Eliza Hall Institute on matters relating to immunity and to the susceptibility of influenza virus to iodine vapour. The latter appeared to have some possibilities in air sterilisation under conditions of crowding with concentration of infective particles.

From the service point of view not much was achieved in the prevention of influenza, because no large scale epidemic occurred. Burnet has pointed out that even in severe epidemics the morbidity rate does not reach 50 per cent, and that this can only be due to differences in the immunological reactions. Attempts to increase resistance are certainly crude, and can be made either by injection of killed virus or introduction into the superficial or deep parts of the respiratory tract of living attenuated virus. Up to the end of the war it had been shown that both methods could cause rise in antibody titre in the serum. Intranasal inoculation has been proved practical: whether it would be effective in a serious pandemic was not answered by the work done up to the end of 1945.

Though most of the work was done in Victoria and references to epidemics were made with regard to that area, these outbreaks were also seen in other States. The lay public and the servicemen spoke of "Puckapunyal", "Ingleburn" or "Woodside" throat and similar names, as though these camps were responsible for a unique type of disease, but the general pattern was similar in all areas. As pointed out earlier, there were individual differences in different places, both in clinical characters and bacteriology. For instance, Rudd isolated a virus closely related to the "Melbourne" type at Puckapunyal, and Jessica Mawson as well as finding *A* type virus in South Australia, noted the prevalence of *Haemophilus influenzae,* whereas Barbara Cook *et alii* did not isolate a virus but found *H. influenzae* in 90 per cent of cases, and also in a significant number of apparently normal recruits.

PNEUMONIA

Pneumonia was not a disease of greater importance in the Services than in similar age groups in civil life. In the Middle East the disease was usually mild. In Palestine, for example, total dosage with sulphapyridine seldom exceeded 20 to 25 grammes, and in Syria during the cold winter following the campaign an increased number of cases was seen, but of mild type. It was noted then that a large proportion of these were of the benign focal type. Where streptococcal infections were common, as in the instance previously noted, a greater proportion of empyema was found. Both broncho-pneumonia and lobar pneumonia were seen in the training camps in Australia, especially during the winter months, but the graphs showed curious "spikes" of short duration, illustrating the epidemic tendency of pneumonia.

Coccal types of pneumonia need not be further discussed here. The drugs used chiefly were sulphapyridine in the earlier years, and sulphamerazine later. The latter was by arrangement made in Australia, being chosen partly because of its rapid absorption and relatively slow rate of excretion, and partly because of a hope that it might be effective in malaria. When penicillin was first available supplies were limited and it was only used for special conditions due to organisms sensitive to penicillin or resistant to other drugs. Later it was used with greater freedom, and observations were made on its dosage and action in pneumonia. The

rapidity with which the radiographic signs cleared was especially noted in the Heidelberg Military Hospital in 1944. Concentrated penicillin was then found to give good results in pneumococcal pneumonia, and injections every eight hours for one day and every twelve hours for three days gave excellent results. The dosage used was one hundred thousand Oxford units dissolved in one millilitre; while this method used more than the customary amount of penicillin it had the advantage of disturbing the patients very little.

PRIMARY "ATYPICAL" PNEUMONIA

The so-called "atypical" pneumonia which has attracted so much notice during the war was frequently encountered among the Australian forces. Probably it occurred much more often than was known, as only X-ray examination will reveal the lesions with certainty, and this was often not practicable. The clinical features need not be recounted here, but the features observed tallied well with other observations. The rather gradual onset, the constant feature of a cough at first dry, and later productive, and the usual accompaniments of a respiratory and mildly toxic disease were "atypical" in the sense that they were not characteristic of any special infection. On the Australian mainland and in all fronts occasional cases were seen, even in the tropics. From the Middle East, from the northern coast of New Guinea, and Bougainville, from Northern Queensland, both on the tableland and coast areas, cases of this disease were reported. Frequently the illness presented itself as a pyrexia of undetermined origin, but the suggestive though usually scanty fine accompaniments to breath sounds or the surprisingly extensive X-ray signs with their diffuse hazy shadows usually told the story. Pleural involvement was rare. Drugs such as penicillin and sulphonamides had no specific effect. Where tests for cold agglutinins could be carried out, an increased titre of agglutination of human red cells was found in a small proportion. In view of difficulties of diagnosis, uncontrolled figures are probably not trustworthy, but the following represent a period when "atypical" pneumonia was being looked for by physicians:

	Rates per 1,000 per year	
	1943	1944
"Colds" and Coryza . .	20.81	12.95
Sinusitis	0.89	3.78
Pneumonia (unspecified) .	3.3	2.6
Atypical pneumonia . .	0.03	0.12

The lack of correspondence between mild epidemic respiratory infections and pneumonia of various types will be noted.

In Changi gaol, Singapore Island, respiratory disease was common owing to the crowded conditions and low resistance. In one month fifty cases of mild pneumonia were seen, but the exact nature of these is not known.

The appearance of this disease in tropical zones was as a rule due to its being carried there from centres of infection known to exist, in the present instance, in Australia or U.S.A. In December 1943 when American troops were present in Australia in large numbers, one unusually severe outbreak occurred in one area near Sydney.[1]

Toxicity varied in this outbreak from slight to extreme. Cyanosis, dyspnoea and other severe symptoms appeared in some patients, one of whom died. Extensive pulmonary lesions were demonstrated radiographically. No predominant organism could be demonstrated in the sputum or in the lungs after death. The infectious nature of the disease was evidenced in this outbreak by the spread of infection to men occupying adjacent tents, and to the contacts such as a nurse attending one of the patients. Cases were observed both before and after the arrival of these troops in Australia. The severe nature of the illness caused some concern lest there be some further local spread to Australian forces, but none occurred. One curious and perhaps coincidental feature was observed, the similarity to the fatal pneumonic infections seen in 1918. In this respect it is notable too that the same age group was affected. Reverting to Australian cases, no definite signs were seen suggestive of encephalitis, which has occurred in some outbreaks, except perhaps a well-marked lethargy of mind seen in some patients. It is, however, perhaps worth recalling that numbers of cases of acute infective polyneuritis occurred here and there during the war, and that some of these had a mild febrile beginning. Such syndromes have been described, for example, by MacDonald Holmes. It is possible that nervous lesions like these, and like serous or lymphocytic meningitis may be associated with atypical pneumonia, for the focal signs of the latter would not always attract special attention.

Australian physicians and pathologists were particularly interested too in the possibility of the occurrence of Q fever and psittacosis in the troops, since these are both familiar in Australia. So far as is known no Q fever was encountered, though the extremely contagious nature of the rickettsia (*R. burneti*) under certain experimental conditions is known. Psittacosis virus was thought of and looked for in a limited number of patients with an apparently non-coccal lung infection, but no evidence of the human form of this ornithosis was found. In both diseases, except in laboratory infections, association with animals or the vectors concerned is necessary; perhaps the conditions were not favourable. It seems curious that Australian medical officers had no opportunity to add to observations made in Queensland on Q fever, though the New Zealand forces in Italy had considerable experience of it.

Australian experience with primary atypical pneumonia coincides with that gained before and during the war elsewhere. Though it is difficult to establish the diagnosis except in well-equipped units, there seems reason to believe that this is a disease entity, though this is an assumption only

[1] Access was given to patients and records by courtesy of the Commanding Officer and the Senior Physician of 118th General Hospital, U.S.A., then at Herne Bay, Sydney.

in the absence of accurate aetiological information. Whether pneumonia described as the "benign focal" type is the same in nature is hard to say, except that a rapid resolution is usually seen with sulphonamides and penicillin in mild coccal pneumonia, but not in the "atypical" variety.

Occasional instances of pneumonic consolidation were also seen associated with eosinophilia. The cause was obscure. They were distinct from the so-called "tropical" forms of eosinophilia, and were not due to a pulmonary stage of infestation by hookworm and similar parasites. They were similar to the condition described by Loeffler. The question of allergy was of course raised, but was not further elucidated.

ASTHMA

Asthma in the forces was not a frequent cause of invalidity. The overall incidence never rose to 2 per 1,000 per year. In 1943 and 1944 when the figures for Australia were 1.74 and 1.86 per 1,000 they were only 1.3 and 0.8 for New Guinea. The increased incidence in certain areas is, however, of some interest. In the Northern Territory there seemed some reason for believing that pollens or other aerial allergens were responsible for many cases in susceptible men. Men who had previous attacks of asthma but who had been for some time quite free of symptoms broke down here and in several other areas, such as Bougainville. Some men after treatment were sufficiently relieved to return to their units, but others were unfit for further forward service.

In Malaya and Thailand asthma was a relatively common complaint. Many men had been returned from Malaya to Australia before the outbreak of the Japanese war. Harvey reported that asthma was common in the 2/10th Australian General Hospital; patients with acute bronchitis often had asthmatic symptoms as well. It is of passing interest that a man who died of what was thought to be septic broncho-pneumonia in Malaya, was found *post mortem* to have melioidosis. Many others suffered from asthma afterwards. Some, but not all of these, had a previous allergic history. At Nakom Paton for instance, respiratory infections were uncommon, but numbers of patients sought relief from asthma for which ephedrine could not be used, on account of its scarcity and its being needed for spinal anaesthesia. Usually bouts lasted four to five days and then disappeared. A botanist grew a stramonium-like plant from which extemporised cigarettes were made with great relief to the patients. In Changi gaol also from 1944 onwards there were a few cases of asthma, and here too relief was gained by smoking stramonium grown in the gardens.

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CHAPTER 21

TUBERCULOSIS

PULMONARY tuberculosis was of course the only form of tuberculous infection of importance in the Services. That it was not of even greater importance and magnitude as a problem of health was chiefly due to the early use of miniature X-ray examination of recruits for the armed forces. The story of the introduction of this method is told in the section on radiology and may briefly be retold here. The question of making a radiographic check of the lungs of all recruits had been for some time before the war under consideration by Major-General Downes, Director-General of Medical Services. The drawbacks of using large films for mass surveys were realised, though early in 1939 Dr H. W. Wunderly, of Adelaide, under a grant from the National Health and Medical Research Council, had conducted a survey of 3,500 young women between the ages of 15 and 30 years. Those who reacted to the Mantoux test were examined by radiography on 17″ x 14″ films. On learning of the successful use of 35 mm. film for photographing the image on a fluorescent screen in a large scale survey in Germany, Dr Wunderly tried this method, and brought it to the notice of Colonel S. R. Burston, D.D.M.S. of the South Australian Military District, and Dr J. H. L. Cumpston, Director-General of Health. The 35 mm. fluorograph was then attracting notice in England, and on receiving Dr Wunderly's letter Dr Cumpston asked Dr C. E. Eddy of the Commonwealth X-ray and Radium Laboratory to report on the technical problems involved. As told elsewhere, the value of the method was soon established, and the personal efforts of Dr Eddy, Dr J. O'Sullivan and Major E. L. Cooper soon placed it on a practical basis. So it came about that a locally made apparatus for miniature fluorography was recommended in October 1939 for examining recruits for the volunteer force for service overseas, and before the end of December 1939 the first miniature set for the use of the Australian Army was ready.

In spite of the loss of the first set by accident, the members of the 16th Brigade of the 6th Division, A.I.F., were all radiographically examined before embarkation early in January 1940. Most of the administrative problems concerned with miniature fluorography in the services are matters for the operational part of this history, but some of them involved also the clinical aspects of tuberculosis. One of these problems was related to the differences in the constitution of the two distinct forces in the Australian Army, the volunteer A.I.F. prepared to serve anywhere, and the militia called up for periods of training and for home defence in a limited area. Though X-ray examination of the chest was at once employed for the whole A.I.F., and rapidly extended to the navy, the air force and women's services, opposition was raised to its use for the militia, in spite of strong advocacy by the army medical service. Only in South Australia were members of the militia radiographically examined from the begin-

ning, and then chiefly through local initiative. General application of radiographic tests to the militia forces was not made till 1942.

The result of this short sighted policy was that numbers of men were brought into the militia ranks suffering from pulmonary tuberculosis. Unfortunately, existing repatriation legislation did not provide for their acceptance for benefits. They were, therefore, not eligible for pension rights or treatment under the Repatriation Commission. They could not be easily discharged from the army as the facilities for handling them in civil institutions were meagre in most centres, and thus they were held in army hospitals for considerable periods. This may have done good in the end in two ways. It emphasised that Australia, though a country favoured with a low tuberculosis rate, was laggard in providing and coordinating the weapons for controlling the disease. It also showed that, as neither civil nor repatriation hospitals would be able to cope with the number of servicemen and women with tuberculosis for some time, their care would be an army responsibility. As will be shortly told, a special organisation was built up for this purpose, and maintained by the army after the end of the war until such time as the Repatriation Commission was able to take over the base hospitals.

Had the micro-film test not been applied to militia troops in 1942, the position would have been still more difficult. A War Cabinet Agendum pointed out that as 250,000 trainees were about to be called up, some 2,500 might have shown radiographic lesions and perhaps one-half (more probably one-third) of these might have been found to be active.

Though tuberculosis continued to appear, as it will among young adults, there is no question that much invalidity was saved by radiography. The early discovery of pulmonary infection was of importance; not only did it give rejected recruits an opportunity to recover, but it limited contagion among non-immunes. The financial argument of outlay saved to the community was used to offset cavils at the cost of taking X-ray pictures and in support it was pointed out that 2,400 soldiers of the 1914-1918 war were pensioners of the Repatriation Department for tuberculosis. A much sounder argument is, of course, based not on questions of the cost of repatriation benefits, but on the health of the community. The cost of the micro-film method was in any case small. Careful records were kept in all commands, and the average cost per recruit was found to be 5d to 6d, including all costs of staff and material, and allowing for the larger films wherever there was a doubt. Even charges for maintenance and depreciation brought the cost to only 10d a recruit.

Naturally the accuracy of the miniature method was a matter of great interest and importance. Though assailed at first by some radiologists, it soon proved itself. Great care was taken in the interpretation of the micro-films. Teams including two radiologists and a physician viewed enlarged images of the films, and either accepted or rejected each; where a film was technically unsatisfactory or revealed shadows suggesting a lesion tuberculosis or otherwise, a 17″ x 14″ film was taken. No recruit was rejected on the evidence of a small film alone. Care was taken, too, to

avoid fatigue of the examining teams by unduly long sessions. During 1940 alone over 100,000 X-ray examinations were made. The results were surveyed by Major J. D. Galbraith. Radiological evidence of active or latent tuberculosis was found in 1.04 per cent of those examined, and a little over half of the foci were thought to be active. Some of the early opposition and prejudice which were encountered, as all innovations must, arose because of a claim that pulmonary lesions are sometimes missed by the miniature method. Experience has shown that this source of error is small. Each recruit's micro-film was kept, and as time went on comparison with films taken at later dates gave opportunity for critical survey. In one series of 14 men with proven tuberculosis it was shown by reference to the original micro-film that some evidence of infection was present on enlistment. This is not a fault of the technical method, but of interpretation. It is of course admitted that occasionally tubercle bacilli can be demonstrated in the sputum of persons whose chest radiographs, even on 17″ x 14″ films, show no apparent lesion. Radiologists have also questioned their ability to decide on the question of activity of a lesion of the lungs on the evidence of a miniature film alone. With this all would agree. Indeed, activity can often only be surmised from X-ray films of the chest, and an opinion is sometimes a dangerous guess. In any case, infectivity of a lesion is not the same as clinical activity, and bacteriological methods alone can tell that.

The criticism was also made that recruits were sometimes rejected for non-tuberculous lesions. This happened occasionally, of course, but the military question at issue was the acceptance or rejection of each individual. Examiners were instructed not to use the diagnosis of pulmonary tuberculosis, but to preface it with "suspected" or "query". All rejects were informed as to any doubts of their physical condition and referred to civil clinics for further investigation. In this connection the difficulty of delay in recruiting depots may be mentioned. Though of administrative rather than clinical interest, this was an important matter. It was obviously important not to absorb a number of recruits and allow them to begin training in propinquity with others before their eligibility was established. Care was taken in various ways in different commands to avoid undue delays. As a rule finality could be given in three days, and the delay seldom exceeded a week, even when repeat X-ray examination was necessary.

A most important check on the accuracy of radiological diagnosis in this military survey was begun by Major R. Webster in 1940, and the results were published in 1941 and 1943. With full military cooperation and all the advantages of discipline it was possible to investigate recruits whose chest films showed evidence of tuberculous infection. In the laboratory these men were paraded fasting, and the contents of the stomach were aspirated unless a satisfactory specimen of sputum could be produced on the spot. Direct smears were made from sputum and acid-fast bacilli so found were accepted as tubercle bacilli. Cultures were also made, and organisms with characteristics of tubercle bacilli grown from these

were accepted as such if they were obtained from sputum of a man diagnosed as having "active tuberculosis". Cultures from gastric contents or from the sputum of men whose X-ray report indicated an inactive or healed lesion were accepted as tubercle bacilli only if guinea pig inoculation into guinea pigs caused progressive tuberculous lesions. This work among army recruits in 1940 proved of such value that it was extended to the navy, air force and women's services in 1941 and 1942. The validity of Webster's cultural criteria were confirmed by Phyllis Anderson working for the National Health and Medical Research Council. Acid-fast saprophytes were not found to be a serious source of error. Further, there was no doubt that in the vast majority of instances tubercle bacilli demonstrated in the gastric mucus were derived from a lesion of the lung.

In all 1,630 individuals were examined, 1,548 being recruits suspected of pulmonary tuberculosis. In 364 tubercle bacilli were demonstrated, 25 per cent by smears, 75 per cent by cultures. The results can thus be summarised:

Number of recruits	X-ray diagnosis	tubercle bacilli cultured
505	active lesion	272 (53.8%)
237	doubtfully active	37 (14.3%)
374	quiescent or healed	21 (5.6%)
224	aberrant shadows of doubtful nature	21 (9.3%)

In four other men examined for various reasons, tubercle bacilli were found in the absence of radiological lesions. This research showed the high value of confirmatory bacteriological investigation in radiographic surveys, and also confirmed the dependability of the micro-film method. Later an instruction was issued that bacteriological examinations would cease as a routine measure in recruits who showed any radiological abnormality in the lungs. This was in no way critical of the value of the work: it was due to the growing demands of war. Naturally a certain delay was unavoidable with cultural investigations. Webster found that a positive report could not be returned in less than three weeks, and a period of six weeks was needed to give a final reply in every instance. D. B. Rosenthal found the average time for 130 tests was 24 days, and that about 10 per cent required six weeks.

There was, of course, no reason why this precision method should not be used where decisions were important and dependent on exact diagnosis. It is important to state that no recruit was discharged from the Services solely on the grounds of an X-ray report. It must also be pointed out that these military experiences have emphasised that in civilian surveys for tuberculosis X-ray examination is only the beginning. The problem for the future is the disposal of those suspected or proved to have active pulmonary tuberculosis. The outlook of public health authorities must be changed by the introduction of mass radiological surveys. Hitherto calculations of the hospital and clinic accommodation needed for those infected with tuberculosis had been based to some extent on mortality or

at least gross morbidity figures. Now rates of incidence as revealed by comprehensive surveys are of dominant importance.

There is little of significance to report on tuberculosis from the various action fronts. In Palestine, through an unfortunate error in administration, a number of men suspected of tuberculosis on radiological grounds were sent to Palestine with the first convoy from Australia, despite the efforts of the medical services to have them sent back. No harm was done, save to the spirits of the men, but most of them had to be held in hospital for months till the first hospital ship arrived.

Arrangements were made for the segregation of men with tuberculosis in service medical units and special accommodation was provided in hutted hospitals. When in 1941 the 2/6th Australian General Hospital took over the 62nd British General Hospital in Palestine, this duty involved the care of a special tuberculosis ward to which all tuberculous British soldiers in the Middle East were sent.

Difficulties were found at times in the disposal of soldiers with tuberculosis. Once the disease is recognised as of infective origin it is perhaps inevitable that it is regarded as highly contagious, even on casual contact. Thus in the more distant Pacific areas patients could not be easily moved; neither aircraft nor transport vessels would take them and only hospital ships would carry them. Occasionally there, as elsewhere, rapidly cavitating lesions were discovered in men who had apparently been well a short time before. Efforts were always made to prevent dispersal of tuberculous patients, but these were not always simply translated into action. Contact was prevented as far as possible between susceptible native races and soldiers with infective states like tuberculosis. The Angau organisation in New Guinea recognised this, and in Northern Territory of Australia the Deputy Director of Medical Services had pointed out in 1942 that the local aborigines were subject to rapidly progressive and fatal forms of the disease. In the latter area suspects among soldiers were received in a special centre in the 121st Australian General Hospital at Katherine, and here men were held who were not taken by the Repatriation Department or were unsuitable for sending south. There were also occasional difficulties in the disposal of female members of the services with tuberculosis, as appropriate facilities in some centres were not always available.

Prisoners of war with tuberculosis were severely handicapped. Those in the European zone suffered from varying degrees of impaired nutrition, but the prisoners of the Japanese were subjected to much greater hardships in every way. It is not surprising that a higher proportion of men with pulmonary tuberculosis have been found in those returned from Japanese prison camps than among others. However, the medical officers of the hospitals in Singapore, Burma and Thailand have noted the comparative rarity of the disease in Australian soldiers, and remarked that considering the poor state of nutrition of these men the small numbers was a tribute to the selective examination of the force. In Changi, it was twelve months before the first case of tuberculosis was demonstrated among the A.I.F., whereas 30 had been recognised among British troops in the first six

months. In this area an excellent clinic was run jointly by British and Australian medical officers where methods such as artificial pneumothorax and phrenic evulsion were practised with good results. Major Fisher in 1945 in Nakom Paton had only 5 Australians among 56 patients with tuberculosis; the remainder were chiefly Dutch and British, in that order. In August 1945 there were 64 patients with pulmonary tuberculosis collected in Changi, but few of these appeared to be recently infected. Cotter Harvey at Kranji found only two fresh infections in two years. When the men in Singapore were liberated, of 1,266 radiologically examined (apart from patients already under treatment) only 28 suspicious films were seen, about 2.2 per cent. Not much could be done for these men during imprisonment, but as liberal a diet as possible was given, and in a few favourable cases artificial pneumothorax was carried out. A group of A.I.F. officers and men in Rabaul were exposed to an atmosphere heavily impregnated with silicate dust after the volcanic eruption just before the Japanese landings were made on New Britain. The possible danger of this dust was not fully realised at the time, but it seems significant that out of 66 men 5 developed pulmonary tuberculosis while imprisoned in Japan.

Mention has been made of the difficulties with regard to the official acceptance of a diagnosis of active tuberculosis. On occasion a diagnosis made by a final army medical board was not accepted by the Repatriation Commission. Convincing clinical standards cannot be laid down for the diagnosis of active tuberculosis, but finally a service instruction was issued embodying principles acceptable to all parties. This technical instruction to medical officers laid down that this diagnosis was not to be made unless:

(a) the tubercle bacillus was found on at least two occasions in sputum expectorated in the presence of a medical officer or member of the nursing services, or in the gastric contents, or in pleural fluid, or
(b) the diagnosis was agreed upon by a medical representative of the Repatriation Commission, who should be afforded the opportunity of seeing the patient attending the medical board, or examining the clinical notes and evidence before the board met.

In the later years of the war the number of servicemen needing treatment for tuberculosis increased by accumulation. Although the incidence rate per 1,000 per year for the years 1942 to 1945 was only 1.14, the total number over this period was 1,334 in Australia, 74 in the South-West Pacific Area and 92 in the Middle East. Of these totals there were still considerable numbers requiring active treatment, therefore it was decided in 1944 to concentrate all men and women from the army at one hospital, the 106th Australian General Hospital at Bonegilla near Albury. Arrangements were made to take members of the R.A.N. and R.A.A.F. also, and when a large British fleet arrived in the Pacific area 110 beds were promised for the use of the Royal Navy. Treatment was coordinated at this hospital under Lieut-Colonel H. Wunderly. There were many administrative problems to overcome. For example, discipline was

not simply applied to a mixed population of patients belonging to different services or under the care of repatriation. Frequent changes of nursing staff were another real problem, and delays were considerable before satisfactory arrangements could be made for necessary surgical treatment of special kinds.

In order to maintain continuity of treatment a General Routine Order (71/45) was promulgated enabling patients with tuberculosis to be kept twelve months in service hospitals before they were brought before a final medical board. An interim board examined them after six months and determined if their condition was sufficiently stabilised to warrant their discharge, when they were placed under the Repatriation Department. Members of the R.A.N. and R.A.A.F. were sometimes boarded at once or transferred to repatriation sanatoria if suitable, but by the end of the war the three Services standardised their methods of dealing with these patients. As a result, more of the members of these Services were retained in service hospitals for treatment.

The need outran the accommodation at Bonegilla and though high priority was given to building originally, to save time waiting for more permanent structures in capital cities, belated approval was not given for the erection of more suitable wards till some months after the Pacific war had ended. Some months later the Royal Navy removed their own patients to England, but beds thus freed had to be kept for prisoners of war then arriving.

It was not possible to concentrate all patients at Bonegilla, and gradually as facilities were available in the base hospitals, patients were moved to hospitals in their own home States. In order to cope with this extension of the army organisation for tuberculosis, a survey of the base hospitals was carried out, for it was evident that responsibility for the care of men and women with tuberculosis would remain with the army well beyond the war period. Therefore a chest wing was opened in the base hospitals of all the State capital cities before the Repatriation Commission began to take over these hospitals. It is interesting to note that the accommodation then available in base hospitals for tuberculosis depended a good deal on the power of paludrine to control relapses of benign tertian malaria.

At Bonegilla a high standard of treatment was maintained. Due care was taken that nurses and other attendants were not exposed to risk of infection. They were subjected to skin tests with the purified protein derivative of tuberculin, and reactors to this test were allowed to work in the wards only if X-ray examination of the chest showed no lesion. Non-reactors were re-examined at intervals. On one occasion a non-reactor showed a reaction within a few weeks. Efforts were made to minimise the risk of infection from sputum by the use of masks and waxed inserts for sputum mugs; and by control of dust by oiling. The Australian Red Cross Society was helpful in these matters.

Little can be said about the results of treatment, as patients were not under unified control for a long enough period for figures to be of value. The full resources of modern treatment were available. Artificial pneumo-

thorax was employed whenever indicated. Over 100 patients were having this form of treatment at Bonegilla at June 1945. In some both lungs were involved. Pneumolysis was carried out where adhesions prevented satisfactory collapse of the lung. Phrenic crush was found a useful adjuvant with suitable indications. More extensive procedures were approached with care and undertaken only after full consideration and consultation. Streptomycin was obtained in limited quantities after the end of 1945. Promin jelly gave promising results in the treatment of fistulae.

The need for the general adoption of standard methods was felt at Bonegilla. Patients were not infrequently admitted with extensive lesions, a difficult type to handle. Others arrived with minimal lesions, but treated in varying fashions. Pleural effusions were treated differently in different places, some with air replacement, others without. Though there was no desire to cramp the independence of medical officers, those responsible for handling a large number of patients could not but feel the need for some coordination.

Problems of importance arose in connection with surgical forms of treatment. Numbers of patients required division of adhesions as an adjunct to artificial pneumothorax, and other surgical measures. At first a "shuttle service" was run between Bonegilla and Heidelberg Military Hospital in Melbourne. There all necessary thoracic surgery could be undertaken, including thoracoplasty and lobectomy, but it was found wise to move only well stabilised patients who needed and were ready for major procedures. Moving of patients with artificial pneumothorax for pneumolysis was also inadvisable. By carrying out this procedure at Bonegilla the incidence of effusions and spontaneous pneumothorax was reduced.

Therefore a thoracic surgeon, Major J. Hayward, visited Bonegilla at regular intervals. In the same way it was found that patients whose artificial pneumothorax was begun at Concord (Sydney) or Heidelberg (Melbourne) were better kept there till stabilised, any further necessary surgical procedures being carried out on the spot. This experience is in keeping with that of physicians and surgeons specialising in chest work, but it was of value in underlining the need for complete facilities, including thoracic units, for all forms of appropriate treatment in all institutions caring for patients with pulmonary tuberculosis.

An unusual surgical event relating to tuberculosis may be mentioned here. Howard reported the case of a soldier with a "sucking" wound of the chest who had a pyopneumothorax. This man had a high febrile reaction and clubbing of the fingers, and tubercle bacilli were found both in the sputum and pus from the empyema. Two years before, X-ray examination on enlistment had not shown any pulmonary lesion.

The story of pulmonary tuberculosis in the forces has twofold interest: it tells of a step along the road of prevention, and a further step towards control. The elimination of 1 per cent of recruits who had suspected pulmonary disease was an important contribution to the war effort; so,

too, was the coordination of treatment for a time under one authority. It is hoped that a greater plan will rise out of this example.

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CHAPTER 22

VENEREAL DISEASES

BEFORE the 1914-1918 war and even at its beginning, powerful taboos still imposed an obstacle to the fullest realisation of scientific methods in the prevention and treatment of venereal diseases. It might have been expected that in 1939 these inhibitory influences would have disappeared. In the main this was so, and in 1940, 1941 and 1942 the realistic measures taken in caring for this aspect of health of troops overseas reflected an enlightened viewpoint. The swing from the predominantly moral outlook to one which was predominantly medical was felt by some to be excessive, but the old rigid disciplinary measures were still being applied with unwise rigour in parts of Australia. The isolation wing of the 107th Australian General Hospital at Puckapunyal in Victoria in February 1941 was a compound under armed guard supplied by the camp duty unit. There were still non-medical officers in the army who regarded soldiers with venereal disease as criminals, though this attitude produced among them the atmosphere of a prison camp. No coordinated prophylactic measures existed, and preventive outfits were not readily available to units. Fortunately a picket of convalescent patients soon replaced the guard, and finally it too was abandoned. This instance was not typical of the general military policy however, and in the Middle East prompt measures were adopted.

By March 1940 a special treatment centre under Major N. W. Francis was attached to the 2/1st Australian General Hospital, and a few months after, fifty beds were available in special accommodation, where work began as an independent unit. As was expected, facilities for the training force were needed early. Prophylactic centres were provided in each camp and kept open day and night; these were the responsibility of the units concerned, and their medical officers acted in an advisory capacity. Standard procedures were drawn up and later embodied in an official administrative instruction. An important forward step was made in 1942 when the control of preventive measures was vested in experts in venereal disease. By contrast, prophylactic centres were not systematically organised in Australia nor well sited, nor was a code of standards for prophylaxis and treatment drawn up there till 1943.

Even admitting that a certain amount of venereal disease seems inevitable in any military community near urban areas, the incidence rates during 1940-1941 in the Middle East were too high. These rates were 35.21 per 1,000 in 1940, and 48.46 in 1941; for these years the corresponding rates for all forms of infectious disease (including the venereal) were 275.09 and 219.67. These rates for venereal disease were certainly much lower than the 79.89 per 1,000 experienced in the First A.I.F. in Egypt in 1916, but, as the Consulting Physician to the Second A.I.F. in the Middle East pointed out in May 1941 in a review of the position, the incidence was "unnecessarily high and caused a constant drain on man-

power". It should at once be realised that even these rates as quoted understate the true incidence, for military statistics are based on bacteriological confirmation. The so-called "non-specific" urethritis, which will be fully discussed later, is responsible for a fallacy. Though usually no less of venereal origin than proven gonorrhoea, and probably due to several causes, it is excluded from most statistical surveys, or treated as something apart from those diseases which have an undisputed aetiology. A War Office letter of 5th October 1940 directed that when doubt existed a diagnosis of "urethritis" only be made, and classed as a disease of the generative system. At the time when the high incidence of these diseases was disturbing the officers of the A.I.F. Headquarters Middle East a survey of the period April-August 1941 showed that of 327 cases of officially proven venereal disease 15 were classed as syphilis, 151 chancroid, 144 gonorrhoea and other varieties 17, but 243 cases of "non-specific urethritis" occurred during the same time.

The loss of men from training and military operations caused a good deal of uneasiness, for the average time then spent under treatment was nearly four weeks, during which the men were virtually useless. Men from combatant units were keener to be cured and to rejoin their units than troops from base or depot units. Naturally a higher proportion of patients in special hospitals came from the latter, as the best and fittest men were soon reabsorbed into their own units. It was impossible to overlook the reasons for the considerable incidence of these diseases. The cities and towns of Palestine with their mixed populations were full of temptation for soldiers on leave. Prostitution, though officially discouraged in the Jewish cities, was a major problem, and even hygienic control was most untrustworthy as a preventive measure. Cairo and Alexandria were worse, with a large prostitute population, practically all infected. Even placing the worst areas out of bounds was a measure difficult to enforce. Syria and Lebanon introduced a most difficult problem, again with mixed populations, and with an inheritance of easy-going methods tolerated under the previous regime. In Greece, before the swift campaign gained impetus, it was noted that syphilis was not infrequent amongst men reporting with infections. Even in Crete in May 1941 during the early lull considerable numbers of men were found to require attention for venereal disease.

Up to the summer of 1941, an average strength of 76,000 troops in the A.I.F. produced about 40 cases of venereal disease per 1,000 per year, excluding non-specific urethritis, the inclusive rate being 67 per 1,000.

During the occupation of Syria the venereal risk continued; the rate for 1942, when little more than one A.I.F. division was in the Middle East, was 47.22 per 1,000 per year. The A.D.M.S. of the 9th Division A.I.F. (Colonel H. G. Furnell) reported at the end of March 1942 that the problem in Syria was still a serious one "especially with the Australians who appear to be either more promiscuous or more careless". There can be no question that alcohol played a part in lessening caution and control.

The measures taken to counter these diseases included educational activities, intimate group talks with men, amenities for sport and diversion, physical training, discipline through control and penalty, prophylactic centres in all more or less settled areas, availability of preventives on request, and control of prostitutes. Sometimes it was possible to identify infected persons and to hand them over to civil police. Educational methods included the issue of special pamphlets to men going on leave, emphasising the importance of preventive measures, and the giving of addresses of prophylactic centres where these were available. Later, strip films were distributed through the Services and were found most valuable. Discipline through curtailment of pay to men with venereal infection was the subject of much discussion. Soldiers soon realised that "non-specific urethritis" was not visited with loss of pay, and surreptitiously took tablets of sulphonamide drugs to mask the true diagnosis of gonorrhoea. The headquarters of the A.I.F. in the Middle East sanctioned an order which imposed forfeiture of pay on men who had contracted the disease otherwise than accidentally in the course of duty, or in a congenital form, and then only after 35 days. This encouraged men to report early, and was of undoubted value. In June 1941 this order was cancelled by order from army headquarters. In 1944 following the practice of the navy, the measures laid down in this A.I.F. order were adopted as uniform practice by all Services.

Experiments in control were carried out in Palestine and Syria in 1941 and 1942. Immediately after the fighting ended in Syria steps were taken to control brothels in Tripoli, Latakia and other centres. Colonel F. Kingsley Norris, A.D.M.S. of 7th Division A.I.F., reported fully on the experiences of this division over a period of fifteen months in the Middle East. All the measures described above were vigorously pursued. Preventive outfits were issued free on request from most aid posts, in some units a nominal charge was made, but all did not agree with this principle. The siting of prophylactic centres in some cases negated their value, for example in police barracks, but improvements were soon made. In Beirut during 8 weeks when leave was granted no less than 18,000 attendances were registered at the divisional prophylactic centre. This is a horrifying figure, yet venereal infection occurred only once in each 443 attendances. In the Tripoli experiment 134 cases of suspected venereal disease occurred out of 13,500 troops in a period of 12 weeks. The extent of the social and medical problem is made even clearer by the fact that there were in Tripoli over these weeks 11,955 attendances in known and controlled brothels. These brothels were practically free of venereal disease, particularly of chancroid. Since chancroid was the commonest cause of admission to the 14th Australian Special Hospital at Bhamdoun, at this time, there seems little doubt that many of the overt infections were derived from other sources in the villages. Figures for venereal disease infection in Palestine in the 1914-1918 war are of course not comparable, as the conditions were not the same, but an average proportion of 1.13 per cent was constantly under treatment for venereal disease during that Palestine

Campaign, rising to a peak of 2.35 per cent. Even in bad areas like Latakia and Aleppo it was estimated that only 0.23 per cent of the force was affected in 1941-1942. Responsible officers believed that these figures would have been considerably greater if efficient prophylactic control had not been exercised. The most controversial feature of this was brothel control. This was done officially; women were tolerated only if under strict conditions of identification and examination. Gynaecological and bacteriological control was carried out, which at least would reduce risk of infection. The administrative difficulties were considerable. Similar medical control was carried out in the Jaffa-Tel Aviv area, with the help and cooperation of the Provost Corps, a most necessary adjunct in all areas. The institution of these precautions in Jaffa-Tel Aviv was followed by a drop in the incidence rate from 70-80 in November 1941 to 45 in January 1942. It is probable that increased attendances at prophylactic centres were largely due to the "voluntary compulsion" exercised by the men over their fellows, who were more swayed by public opinion than caution.

In October 1942, when the A.I.F. was soon to leave the Middle East, Lieut-Colonel D. B. Loudon reported from the 8th Special Hospital that in 1941, 5,774 cases of venereal disease had been admitted to this unit. He estimated that in the A.I.F. in the Middle East there had been 11,000 cases of venereal disease, 373 of which were due to syphilis. The average stay in hospital was three weeks. He considered that control of prostitution was only partly effective as the amateurs were at least an equal source of danger. Personal protection was rather illusory too, as the men would not use it, even if deterioration had not weakened the reliability of the outfits provided. Loudon proposed a venereal diseases control unit which could move to all units and areas as required. This could aim at abstention as an ideal supported by educational propaganda, control methods of prevention, and see that early treatment was undertaken. Disciplinary action was suggested as a measure to be taken against men who took risks but refused prevention. The prophylactic methods then in use showed no advance on those of a generation before, and it was also proposed that skilled personnel only be employed who would carry out as an additional routine measure the injection of 5 per cent argyrol with a urethral syringe. These measures were never fully adopted, but the training of orderlies was vigorously pursued in special hospitals.

Turning to the clinical aspects in the Middle East, a difficulty early arose with the treatment of syphilis, as a period of eighteen months surveillance was required. For a time the men concerned were drafted into a special company attached to the special hospital, and used for guard duties. Once free from active contagion, they could have been returned to Australia, but so easy a back door of escape to home surroundings was undesirable. Where continuity of treatment could be assured in their units or neighbouring hospitals they were discharged to these units again, but could not well serve under conditions of active warfare. A certain number of bad characters always collected, usually awaiting court martial,

and for these a special compound was necessary. It should be noted that, although detention cells were necessary in special hospitals, disciplinary measures were seldom needed. Indeed, absence of patients without leave was not a frequent misdemeanour in these hospitals. In spite of administrative difficulties, the guard company did useful work. Treatment of syphilis at this stage was by arsphenamine (novarsenobillon) and "sulpha-stab", and as soon as available, after initial delays, bismuth.

Gonorrhoea was treated with sulphapyridine at first, over an average period of 13 days. Later sulphathiazole was obtained and was used instead. It is of interest that evidence of sulphonamide-resistance appeared as time went on: primary cures of gonorrheoa fell from 60-75 per cent in 1940 to 40-55 in 1942. Some local investigations were made into the causes of non-specific urethritis, but not much headway was made. Staphylococci, diphtheroids and trichomonas were often found, as well as other unidentified organisms, but there was no evidence that these played a causal part. Complications of the adnexa were fairly common, sometimes quite early in the attack.

A more scientific classification of urethritis was now suggested from the medical general headquarters in the Middle East: this recognised endogenous and exogenous forms, the latter including gonococcal, non-specific and chemical causes.

Pathological and serological facilities were developed at the 8th Australian Special Hospital in Palestine, greatly to the benefit of accurate and speedy diagnosis. The work of Major C. B. Cox in proving that guinea-pigs could be bred successfully in Palestine, not only made full serological methods available to special hospitals but benefited the pathological services of the A.I.F. in the Middle East.

The problem of venereal disease in other campaign areas will now be briefly outlined; then we may return to Australia and study the position there, with some evaluation of the whole question.

SOUTH-EAST ASIAN ZONE

In Malaya there was nothing unusual to record about venereal disease. In the pre-action phase the maximum incidence was fairly steady at 31 per week in 7,700 troops, though the arrival of a new brigade group raised this figure temporarily to 58 per week.

In Singapore after liberation from the Japanese a number of ex-prisoners of war suffered from chemical urethritis, due to self disinfection methods of undue potency. In spite of this a number of them, especially a group from Thailand, contracted various forms of venereal disease. Chancroid was not uncommon in the South-East Asian Area, and appeared in some of these repatriates. Treatment by sulphonamides was very effective.

THE SOUTH-WEST PACIFIC AREA

In the Pacific Islands venereal disease was not a problem because of lack of opportunity of acquiring infection, and the absence of settled areas

where soldiers might spend leave. The rates of incidence in the army were as follows:

	1942	1943	1944	1945
Strengths . .	23,266	74,872	72,072	104,868
Rate per 1,000 .	2.33	1.06	0.36	7.69

Movement of troops confused the statistical issue somewhat, especially in the later stages of the war when the military operations fanned out over a wide zone.

In the brief campaigns against the Japanese in Borneo and related areas more infections occurred than in former island campaigns, for known sources of infection existed among natives in various areas in Borneo. A small number of cases of syphilis was recorded there, and trouble was experienced with sulphonamide-resistant forms of gonorrhoea.

After the end of the war, but while troops were acting as an occupation force, though often in a state of idleness, the rate of incidence rose sharply. Intractable forms of non-specific urethritis also appeared, unquestionably of venereal origin; even after 70 to 80 days of treatment by all methods, including the use of penicillin and sulphonamides, cure was sometimes not complete. Chemical urethritis was also seen in British Borneo.

IN AUSTRALIA

Venereal disease caused considerable anxiety in Australia by reasons of the risks run by servicemen on leave in towns and cities. The following table shows that there were reasons for anxiety:

Rates of incidence of venereal disease in the army in Australia

	1942	1943	1944	1945
Strengths . .	350,779	380,289	345,004	219,843
Rate per 1,000 .	18.93	16.85	13.18	17.08

Lieut-Colonel N. M. Gibson, Commanding the 120th Australian General Hospital, reported from the N.S.W. area that 85 to 90 per cent of the venereal infections in soldiers were transmitted by amateurs. This made control very difficult. The influence of alcohol in increasing the risks of exposure was also considerable. After a good deal of trouble prophylactic depots were established near all camp areas and in all centres of population. Special care was taken in the selection and training of the staffs. A high standard of cure was insisted upon. In fact it was higher than the standard officially exacted by service instructions, and some critics thought it too high. At this time the average stay in the 120th A.G.H. was 52 days, owing to the reliance placed on the complement deviation test. A steady rise in the incidence of syphilis also caused anxiety when it increased from 4.5 per cent in 1941 to 8.1 per cent of all venereal disease in 1942. Non-gonococcal urethritis was common, varying in different series from 45 to 60 per cent of all forms of urethritis; careful treatment was necessary as complications were not infrequent. Research was carried out in this hospital and elsewhere on the aetiology.

The public health aspects of venereal disease were discussed at representative conferences in Queensland and Victoria in 1942. The need for research was emphasised, also for standards of prophylaxis, diagnosis, treatment and social control. The latter was regarded as of particular importance and strong recommendations were made to the Commonwealth Government to pass regulations under the *National Emergency Act* which would give power to civil health authorities to detain and examine persons suspected of carrying infection. In September 1942 these regulations were promulgated, enabling control of carriers of venereal disease to be effected and prohibiting sale of such drugs and appliances as might be used in disorders of the generative system.

Early in 1943 a uniform statement was issued governing the prophylaxis and treatment of venereal diseases, and laid down standards accepted and used by all the Services. The navy and air force had experienced much the same difficulties as the army. There were, of course, certain differences in the navy. Medical officers called attention to the difficulties caused by overnight leave, which often meant that men reported too late to prophylactic centres. Isolation on ships was a difficulty. Lavatory accommodation was limited, so too was sleeping and messing space. In smaller ships such as destroyers these problems were particularly acute and though treatment was begun at once it was usually more convenient to transfer affected men to hospital when this was possible. Long stay in ports, as for instance when ships were refitting, meant inevitably an increase in venereal disease. Though improvements in outlook and in preventive methods had reduced the incidence over the previous fifteen years it seemed as if no systems of educative effort and prophylaxis could prevent a wave of infections at times.

Air force experience and methods closely tallied with those of the army; and special hospital accommodation was provided, sometimes in units also treating other infectious diseases, sometimes in combined service hospitals.

Details of the standard treatment laid down in 1943 need not be given here. They followed generally accepted lines. Diagnosis of syphilis depended on dark ground examination by a competent pathologist, and later on serological tests. Reference may be made here to the occasional difficulty in interpretation of Wassermann reactions in patients with malaria. In order to distinguish a strongly positive reaction due to malaria from one due to syphilis, a Kahn verification test was tried for a time, sera being submitted to army headquarters. This was not found satisfactory and was abandoned. Francis and Wannan found later that by doing a Wassermann and a Kline test at the same time the two infections could be distinguished. Malarial sera showing a strong Wassermann reaction were found to react feebly or doubtfully to the Kline test unless a syphilitic infection was also present. A ten weeks course each of arsenicals and bismuth, or preferably iodo-bismuthate of quinine was given, the former being repeated if the results of the serological tests were positive, and following with bismuth for twelve months. Disposal of men with syphilis was made according to the stage of the disease and the progress of treatment. Standards of

cure demanded that in early cases the result of the Wassermann or Kline test remain negative for twelve months; no man was discharged from hospital till declared temporarily non-infective. In later cases a special review was made by a board after a minimum of eighteen months treatment. Gonorrhoea was treated by one or other of the available sulphonamides, 2 grammes on admission to hospital, and then 1 gramme every six hours for five days. When sulphamerazine was made in Australia this was substituted, in 2 gramme doses twice daily. Some 20 per cent of these infections were found to be resistant to sulphonamides at first, and as time went on the percentage increased, probably owing to the organisms becoming sulphonamide-fast. Local treatment was given with permanganate of potash 1-1800 and 5 per cent argyrol or equivalent. Massage and sounds were used if adnexal complications ensued. The standard of cure included the examination of post-massage slides taken at the end of treatment and after hard physical training. Dilatation of the urethra and if possible urethroscopy were also carried out. Full information was given in the official booklet about chancroid, or *lymphogranuloma venereum*, which was of importance under service conditions. It responded well to sulphonamides, but patients needed enough observation to ensure that a syphilitic infection was not also present.

The only new method tried in treatment before the introduction of penicillin was the intensive treatment of syphilis by "Mapharsen" given in massive doses continuously over a brief period. Even limited experience had proved unfavourable. Francis and Wannan reported the results of treatment of patients with "Mapharsen" given for ten hours continuously over a period of five days. A death occurred in a series of forty patients so treated, the cause of death being toxic jaundice and encephalopathy. Therefore a ban was promptly placed on this method. In Technical Instruction No. 80 it was pointed out that the risk of fatal accidents varied with the intensity of the treatment. The risk was clearly tabulated as follows:

Duration of treatment	Incidence of encephalopathy	Mortality
5 days	1 in 100	1 in 200
10 days	1 in 100	1 in 300
12 weeks	1 in 1500	1 in 1500-2000
26 weeks	practically nil	1 in 5000

About the same time prophylactic procedures were the subject of a special instruction, which also gave specific directions for the unit monthly parades before a medical officer. Unit medical officers often found these parades useful also for educative purposes, to curb the foolhardy, and to discourage the dangerous practice of only reporting on the last day of leave. Control of venereal disease in the Australian Army was improved by the appointment of a director of venereology, Lieut-Colonel D. B. Loudon, attached to the medical headquarters, and assistant or deputy assistant directors in each area, according to its size and importance. Coordination between the Services and the civilian authorities was on

the whole satisfactory, though in some areas it was felt that more powers could with advantage be vested in the latter in dealing with suspected sources of infection. The Northern Territory had some difficult problems: in the Darwin area, for example, half-castes increased problems of control.

Early in 1944 Lieut-Colonel Loudon reported that there were still weaknesses in control in the army. No complete list of prophylactic centres was available, there was a lack of publicity concerning these, procedures were not always well carried out and methods of training for orderlies did not always conform to a high standard.

When the women's services increased greatly in numbers and were widely diffused over Australia and many forward bases it became necessary to make some provision for the treatment of venereal diseases amongst them. It was not expected that this need would ever be more than minor in degree and experience confirmed this. Among the nursing services these infections were unknown, and in other services the incidence was very small. The highest incidence reached was in Queensland, which was a centre of intense and constant movement with a high military population; it never exceeded 8 per 1,000 per year there for a limited period. The factors concerned no doubt included a fear of publicity, but most important was a higher sense of responsibility, and better educational standards in matters relating to hygiene. The best prophylactic measure was found to be education in personal hygiene.

Special standards of diagnosis, treatment and standards of cure were laid down; these were thorough and included rigid bacteriological control. A woman who refused treatment was not retained in a service. Provision was made for hospital accommodation in special annexes to general women's hospitals.

Before considering the changes wrought by penicillin, we may return briefly to the subject of research, especially into the bacteriologically vague groups of "non-specific" urethritis. In several capital cities investigations were carried out. At the 120th Australian General Hospital in New South Wales 4,000 cases of urethritis were surveyed. Of these half were non-gonococcal. Fifty-one per cent of these were characterised by profuse purulent discharge and many bacteria, chiefly Gram-positive. Forty-nine per cent had some pus but no bacteria. Practically all of these two groups were of venereal origin. A few were due to chemical or traumatic causes. In half the total number organisms of presumed importance as infective agents were found and as similar organisms were isolated from the cervix of infected women a causal role seemed reasonable. The remainder were of obscure origin, consistent with a virus infection. It was from this group that pleuropneumonia-like organisms were isolated. Klieneberger recorded finding these in the human vagina and this work was repeated in Australia.

G. A. W. Johnston at the 120th Australian General Hospital recognised several clinical types of infection, ranging from a mild anterior urethritis to severe purulent conditions often involving the posterior urethra and the prostate. Inclusion bodies were demonstrated in epithelial cells in a number of these, organisms of the pleuropneumonia type. The question arose

whether these acted as secondary excitants or as the primary infective agent. Similar organisms were found by G. A. W. Johnston and Jessica McEwin in exudates.

W. I. B. Beveridge had reported from the Walter and Eliza Hall Institute in 1943 that these organisms could be demonstrated in 6 out of 24 men selected by Squadron Leader K. McLean as having non-gonococcal urethritis. Beveridge and Campbell and Lind carried out complement fixation tests against these organisms; the isolation by culture was also made from 20 per cent of cases of "non-specific" urethritis, and from the genital tract of 17 per cent of normal women examined. The significance of these findings was not certain, but they were consistent with the disease being due to organisms resembling the pleuropneumonia virus, on the analogy of known facts concerning carriers of other diseases. Beveridge found at the Walter and Eliza Hall Institute in 1944-1945 that of 70 cases investigated most were mild in nature, unlike severer types previously seen. The incubation period was about 1 to 3 weeks. Pleuropneumonia-like organisms were found in 14 of these, but none in normal controls.

W. John Close pointed out that quite apart from any suggestion of venereal disease or its complications, a mild chronic vesiculitis of non-specific type was not uncommon in the civil community. Other writers, W. E. Coutts and R. Vargas-Zalazar, have also described a form of abacterial pyuria which appeared to originate by ascending or descending infection of the urinary tract. It has been suggested that the causal agent might be a virus, a spirochaete or other protozoon. The presence of spirochaetes had been recognised in such conditions for a number of years, and successful results have been obtained by injections of arsenic. However, the lack of success of such treatment at the hands of some observers and the varied morphology of spirochaetes make for caution. It is possible that abacterial pyuria may ensue from urethral infection and from blood-spread from another focus. Whether there is a constant cause or not, virus, spirochaete or trichomonas, arsenic seems worth trial. Reference has been made to Reiter's syndrome in the section on infections of the urinary tract. It is mentioned here again in passing, and it may be pointed out that this loosely classified syndrome could hardly be regarded as always causally related to an infection of the lower urinary tract, since so few instances of it were seen among the large numbers of men with urethritis of various causes.

PENICILLIN IN VENEREAL DISEASE

Penicillin has changed the whole therapeutic outlook in the venereal diseases. The end results of treatment of syphilis, particularly with regard to complications affecting the cardio-vascular and nervous systems cannot yet be stated with finality, even though clinicians are less mindful now of latent syphilis. Nevertheless the value of this antibiotic in both gonorrhoea and syphilis was soon established; treatment was simplified and made safer, with the lessened risk of heavy metals. The time lost in hospital was also much reduced. Early use of penicillin for syphilis was based on

a total dosage of 3,000,000 units, 40,000 being injected every 3 hours. Later it was found better and much easier for patients and staff to give 250,000 units twice daily for 8 days, a total of 4,000,000.

Army Technical Instruction, No. 125, was issued laying down the standard treatment for syphilis by penicillin and bismuth. All patients with fresh early infections were so treated, and those whose treatments had begun with arsenic were switched to penicillin. The danger of Herxheimer reactions in nervous and vascular syphilis was stressed, and the conventional preliminary course of bismuth and iodides for six weeks was advised, after which penicillin was given, or before if advised by a senior officer. Bismuth was continued bi-weekly after the penicillin. This method allowed the time in hospital to be reduced to about three weeks, after which the patients could usually be transferred to a works company or similar unit, and attend hospital as an outpatient. The period of observation and treatment was then in all eighty-three weeks. The rapid resolution of all obvious lesions was one of the features of penicillin therapy.

Some of the problems of gonorrhoea resistant to sulphonamides were solved by penicillin, and the creation of sulphonamide-resistant strains lost its previous significance. The carrier state was also found to be much less common than with sulphonamides only. The later introduced slowly absorbent preparations of penicillin have also simplified treatment. Even in the latter stages of the war the great saving of manpower previously lost in hospital for venereal disease was considerable. Three hundred cases were observed in initial trials before penicillin was officially adopted for the treatment of gonococcal infections. In this series 90 per cent were clinically and bacteriologically cured by 100,000 units, this percentage rising to 95 per cent with 200,000 units. The addition of sulphamerazine twice daily for 5 days raised the percentage to about 100 for acute infections. The necessity for adequate drainage of the urinary tract of course remained. It was found that relapses were due to insufficient surgical drainage as a rule and in a small percentage only to penicillin-resistance. Penicillin lowered the risk of epithelial damage with change from normal columnar to squamous epithelium caused by organisms resistant to other drugs. Severe complications lessened in number. The same standards of cure were of course necessary. In women penicillin was found valuable, especially in those forms of infection difficult to eradicate by ordinary means. Special investigation in civilian clinics in Queensland and elsewhere showed this in 1944. *Lymphogranuloma venereum,* though uncommon in Australia, was seen in aborigines at times, and Major F. Boyd Turner found at Alice Springs, where the military hospital undertook all local medical treatment, that good results were obtained with penicillin.

Technical Instruction, No. 104, described the results obtained by using penicillin, and directed that it would be used only for patients who had proven gonorrhoea, or a previous history thereof, and for those with acute anterior infection, with or without the presence of organisms. The combined use of penicillin and sulphamerazine was found in one hospital to

reduce the average stay in hospital from fifty days to less than one half of this.

One other remarkable improvement may be mentioned in the treatment of venereal warts (*condylomata acuminata*). The unsatisfactory nature of operative treatment was accentuated by delays in convalescence. Local application of finely powdered podophyllin resin 25 per cent in liquid paraffin was found to be very satisfactory, and was officially adopted. Pain on application was seldom troublesome, and one to four applications at intervals of four days were usually successful.

A review of the venereal diseases during the war period gives rise to considerable satisfaction from the scientific point of view. Suffering, danger of complications or of risk of transmission of infection have undoubtedly been lessened. The future lot of that most unfortunate innocent subject of the disease, the infected infant, is much happier. It is hard to estimate the changes that have taken place in the impact of these diseases on a civil community. We know that the same improvements have taken away much of the danger and not a little of the fear from men and to a less extent women. The perceptible increase in the percentage of syphilitic infections in the community has been disturbing: possibly the rapid sterilising effect of modern drugs will cause this to fall in the future.

But underneath the medical achievements what changes have been effected in the social milieu? Is it any less difficult to build a sure edifice of prophylaxis on a moral basis? We have seen that evil opportunity waits for many, aided by such influences as alcohol, distance from home, lessened amenities, personal risk in war, and now the relative ease with which cure of venereal disease can be accomplished. Though we are really only concerned with the period of an actual state of war in this history, it is apposite to quote one instance from the experiences of the British Commonwealth Occupation Force in Japan. During part of 1946 Australian troops, though only 25 per cent of the total force, supplied 73 per cent of the venereal disease. There were no doubt intrinsic causes for this high incidence in the men themselves, but there was reason to believe that the publicising of sulphonamides and penicillin have not helped to reduce the incidence of venereal disease.

Though all medical instructions designed to prevent venereal disease attempt to build on the sure foundation of continence and personal responsibility, it is evident that neither such considerations nor those of caution or fear will act as deterrents. During the war remonstrance came from members of the public based on objections to encouraging men to be incontinent without risk. Most medical men will probably admit that to place the armamentarium of protection in a man's hands is open to serious criticism, chiefly because it is in practice often futile. The work of prophylactic centres, if of a high standard, and carried out in the atmosphere of a clinic is based much more soundly, and has been remarkably successful. It is essential for complete success that all procedures are carried out by the attending trained orderlies and never by the soldiers personally.

That a purely medical outlook on venereal disease is undesirable may freely be conceded. There have been definite advances and improvements in the prevention and treatment of venereal infections during the 1939-1945 war. Frankly, these have been based on solely medical issues, and we must admit that little has been accomplished from the moral standpoint. This the doctor, like other citizens may deplore, for he too is concerned with the moral issues. But it is none the less his duty in war to lessen suffering, and to keep men fit for their military duties, using the gifts of science towards these ends.

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SECTION 2 — SYSTEMIC AND CONSTITUTIONAL AFFECTIONS

CHAPTER 23

CARDIO-VASCULAR DISEASES

As most servicemen and women are drawn from a selected age group the varieties of cardio-vascular diseases seen among them differ in frequency from the distribution familiar in civil practice. If the preliminary screening of medical boards is carried out adequately, degenerative vascular disease should be comparatively infrequent, and be found only in the older age groups. No attempt seems to have been made to assist the general judgment of medical officers who have to assess the capacity of older men in the Services in this regard, but this matter is one rather related to the work of medical boards, and will be considered elsewhere. For the purpose of ordinary recruiting examinations special instructions were issued governing the estimation of the blood pressure, though of course this is a very incomplete measure of the capacity and integrity of the vascular system. Formal exercise tests were not as a rule employed, and no standards were laid down, and this wisely avoided undue reliance on the apparent accuracy of mathematical formulae. For the special requirements of the R.A.A.F. the test of blowing up and holding a column of mercury forty millimetres high was found valuable. Lawrence pointed out that it was possible to use trick methods by which true lung air pressure would not be registered, but that this could be circumvented by adding a small air leak to the apparatus.

1. *UNRECOGNISED CONDITIONS*

In spite of precautions, occasional instances of previously unrecognised congenital heart disease or symptomless organic conditions were occasionally seen; often they were not of any particular significance. Mitral stenosis was sometimes apparently missed; perhaps this is not surprising in view of the noisy conditions frequently prevailing in places where recruits are examined. Conversely, young men with perfectly healthy hearts were sometimes rejected for an alleged mitral stenosis, the only departure from the normal resting state being over-action of the heart from nervous causes. Experience proved that when an otherwise healthy, fit soldier is discovered to have a cardiac murmur, great restraint and discretion are needed to avoid the creation of a cardiac neurosis. Even a ward round has contributed to this unfortunate result.

2. *RHEUMATIC FEVER*

Rheumatic fever as a sporadic event has been seen occasionally. A least one epidemic occurred in the armed forces during the war. One

striking outbreak was observed in South Australia, principally in one unit of the Royal Australian Air Force. South Australia, in particular Adelaide, is known as one of the areas in Australia where acute rheumatism is not uncommon among children and young people. Wing Commander R. L. Thorold Grant studied this outbreak in detail. The unit involved was stationed in the old Exhibition Building in Adelaide. Both men and women were employed there, but the male patients far outnumbered the female; this was probably related to the fact that the members of the W.A.A.A.F. did not live there. At the time, 1943-1944, there was no special increase in the number of cases of rheumatic fever occurring in the civil community, as judged by the admissions to the Children's Hospital. Most of the cases conformed to the same type, that seen in juveniles; joint manifestations were on the whole minimal, but there was a high incidence of cardiac complications. This cardiac involvement did not always produce clinical signs, but electrocardiographic records taken at regular intervals revealed many unsuspected abnormalities. These changes usually consisted of lengthening of the *P-R* interval, disappearance of the *S*2 and *S*3, and elevation of the *ST*1 and *ST*2 above the iso-electric level. In many instances such changes were short lived. Sedimentation rates were not found always to be a reliable index of the presence of an active carditis. A history of sore throat commonly preceded the onset of rheumatic symptoms. Most of the patients were treated with salicylates over long periods; sulphonamides were tried also, particularly for relapses, but many of the men were upset by the drug, and no striking results were obtained. The greatest problem in treatment was the handling of the patients over a long period; many were in bed for months, and relapsed when attempts were made to get them up. Even after cure had been apparently complete and the men were back on duty relapses occurred. No prophylactic doses of sulphonamides were tried. The disposal of convalescents in this area raised a problem also, as the available rehabilitation unit was in the hills, where the climate was cold and wet in the winter, and it was found that the men did better nearer the sea. While some of the men recovered well and returned to work, the impression given by this epidemic was that few of those affected were fit for service. It has, of course, been found that recruits with a history of past rheumatic fever are better to be rejected in most cases, unless there has been a long period of freedom from relapse. In 1941 there was an outbreak of rheumatic carditis in an internment camp at Hay. Twenty-eight German Jewish youths, aged 17 to 22 years, had clinical evidence of carditis following tonsillitis. Most of them had haemolytic streptococci demonstrated in throat swabbings, but none had involvement of joints.

3. *NUTRITIONAL CARDIO-VASCULAR DISTURBANCES*

Occasional instances have been seen of cardiac murmurs and enlargement associated with oedema in soldiers subjected to hardship and dietetic restriction which, though of definite degree, gave rise to no more than loss of weight and exhaustion in their fellows. Such unusual events are

probably akin to isolated and unexpected examples of deficiency states occasionally met in a civil community. With these few exceptions cardio-vascular disturbances due to gross nutritional disturbances were only seen among Allied prisoners of war in the hands of the Japanese. Unfortunately the medical officers of the 8th Division during their captivity had many opportunities of observing these states, and their observations were typical of those made in many other places under Japanese occupation. The varieties of circulatory affections seen included oedema, with or without cardiac failure, and cardiac emergencies. Undoubtedly oedema was in many instances due to protein deficiency, without any additional element related to the mechanics of the circulation. But exact classification in aetiological terms was as a rule not easy; dietetic deficiencies were certainly the underlying cause in most cases, but these were as a rule multiple. During 1942 and 1943 the term "cardiac beriberi" was used for many of these conditions, but there is no doubt that there was a grave lack of protein and other essential substances in the dietary of the prisoners as well as thiamin, and the diagnosis was recognised later as one which could not always be sustained on scientific grounds. But, though not always accurate as a clinical description, it had another value. It was one of the few labels that the Japanese understood or would heed, and therefore had some use as a basis for argument in the constant struggle to obtain a reasonably adequate ration. Major Bruce Hunt, senior medical officer with "F" Force, drew up a special report on the subject, based chiefly on the study of 100 British and Australian soldiers, who were used by the Japanese for work on the Burma-Thailand railway. "F" Force, of which they formed a part, suffered terrible privations, and lost up to April 1944 over 3,000 British and Australian men from a total of 7,000. These deaths were due to a combination of diseases of infective and nutritional types and amongst both those who died and many of the survivors were seen extreme examples of deficiency states. In all but two of the camps they occupied the thiamin-non-fat calorie ratio was below the safety level. Oedema was common, often of gross type and associated with effusions into the serous sacs. Some of these men with oedema had neuritic manifestations also, and some had cardio-vascular disturbances, which were also observed in men who had no oedema. The signs and symptoms referable to the heart included palpitation, either spontaneous or induced by exertion, a rapid heart rate, or occasionally an unduly slow rate, irregular rhythm due to extrasystoles or to auricular fibrillation, shortness of breath, a sense of oppression or pain in the chest, dizziness and syncope. Splitting of the first heart sound causing gallop rhythm was often noted, and in half the patients a loud systolic murmur was heard over the heart. Definite cardiac failure occured in a number, predominantly of the left side of the heart. Ventricular arrest occurred in some instances, causing Stokes-Adams attacks. These were recurrent, and sometimes ended fatally. Sudden deaths occurred also in men who had not been thought ill. The only common factors in these sudden cardiac deaths appeared to be that the men had all been existing on an insufficient diet for at least three months,

with a thiamin-non-fat caloric ratio of less than 0.3, had suffered intercurrent infections, and had frequently undergone severe physical strain 12 to 36 hours previously. A number of sudden deaths occurred after train journeys, which were associated with so much fatigue and hardship that they were an ordeal even to men who were relatively well. Following the return of the force from the jungle working camps a more adequate diet was available, and after a period of six to eight weeks no more sudden deaths took place.

It is of interest to follow the remnants of "F" Force after the men returned to the Changi gaol area. Here they could be compared with men admitted to hospital from Allied working parties working under varying conditions of privation. Observations were made and recorded by Lieut-Colonel W. A. Bye, A.I.F., and Lieut.-Colonel W. J. L. Neal, I.M.S. The study of these men made by Major Bruce Hunt while they were in the Kanburi hospital camp in the early part of 1944, showed that they suffered greatly from the local conditions, and, while those in Changi were meagre and poor enough, they were better than those prevailing in the Thailand camps or in Kanburi. It was noticeable that many of the men still complained of shortness of breath, dizziness, palpitation and tightness in the chest. Most of them had been under treatment in Kanburi for many months, and many men were still only lying or sitting on admission to Changi. Usually they made no spontaneous complaint of symptoms referable to cardiac disease; the men were on the whole fatter than the other patients, though flabby in condition, and, while they felt anxious about their condition, they wished to be free from restrictions. The diagnosis of cardiac beriberi had been based chiefly on objective signs such as irregularity and abnormal heart sounds, and was justified in view of the great frequency of thiamin and other deficiencies and the high death rate in the force, largely due to beriberi combined with other infections such as dysentery. Moreover, the Japanese were aware that cardiac emergencies of the type known to them as *"shoshin"*, due to thiamin deficiency, were occurring.

Bye and others in Changi concluded that the condition of these men at the time of their return was not due to beriberi, but to neuro-circulatory asthenia. Steps were therefore taken to verify this diagnosis. Clinical examination showed that the men had a reasonable exercise tolerance, and no enlargement of the heart was detected. X-ray examination of these men was carried out by Major Uhr, who used a standard technique, with the distance from target to screen 27 inches, and employed 3.5 milliamperes and 39 to 45 kilovolts. The results were compared with those obtained by examining a control group of 300 other men undergoing routine check of the lungs. Further comparison was made with two control series, one a group of men from the Changi area who had signs of cardiac disease such as oedema of the feet or face, dyspnoea and oppression in the chest, and the other a group, chiefly Dutch, who came from Pulau Damah Laut working camp, and had signs of gross oedema. The "normal" size of the heart in Changi was found to be smaller than usual,

the heart-lung ratio being 1 to 1.25. The ratio was considered to be pathological when it exceeded 1 to 1.4; it sometimes rose to 1 to 2. Judged by these standards only a small number of men could be classed as having true cardiac beriberi, the chief criterion being radiologically demonstrable enlargement of the heart. When present such enlargement affected the left side predominantly in 66 per cent, the right side 6 per cent, and 6 per cent both sides. Signs of pulmonary oedema were seen, but not constantly, and pleural effusions were uncommon. The men who had proven cardiac enlargement, which was believed to be due to beriberi, were re-examined after two months, when the size of the heart was found to be decreased.

In the majority of the group of 130 men from the Thailand camps no radiological abnormality was found; in only three was the heart-lung ratio increased as seen on the fluorescent screen. On the strength of these results the medical staff at the Changi hospital decided to encourage these men to resume activity again, and placed them on graduated work. This decision carried definite responsibility, but was important. The men had shown evidence of severe malnutrition, and severe anaemia, the haemoglobin value ranging from 70 per cent to 30 per cent, and had suffered from extensive ulcers, dysentery, malaria and other infections, and had without doubt also had varying degrees of thiamin and other deficiencies. Nevertheless the verdict that their hearts had not sustained damage was immensely important to them and to the force. It was considered very doubtful if these men had had true cardiac beriberi, if so it was probably of mild degree. Follow-up of these men was made as far as practicable, and their progress was found satisfactory. No unexpected fatality occurred in this group.

This experience led to a reconsideration of the exact diagnosis of cardiac beriberi, apart from the general use of the term. Bye concluded that cardiac irregularities could not be attributed to thiamin deficiency alone, unless they disappeared after the administration of thiamin. Extra systoles were often found in patients with beriberi, also regular patterns of irregularity, such as bigeminy. They were also common in patients who had no overt signs of beriberi. It was concluded that the diagnosis of cardiac beriberi could not be made with certainty without spontaneous symptoms of heart failure and radiological evidence of cardiac enlargement. The physical signs found in patients believed to have cardiac beriberi included evidence of enlargement of the heart, systolic murmurs at the apex, split heart sounds, irregularities, filling of the neck veins, rales at the bases of the lungs and rarely attacks of pulmonary oedema. Such patients occasionally had sudden attacks of cardiac arrest which will be discussed separately.

Similar experience had also accumulated in Nakom Paton, the huge hospital terminal at which sick men were concentrated after the completion of the Thailand railway. Lieut-Colonel A. E. Coates, chief medical officer, obtained a special report on the subject of cardiac beriberi from Major W. E. Fisher in November 1944. Fisher considered that a general

diagnosis of beriberi for all forms of oedema was justified, as it was certainly an important factor and the only one significant in the eyes of the Japanese. He did not think, however, that all varieties of disturbances of rate or rhythm warranted a label of "cardiac beriberi", and recognised the danger of communicating to the men the idea that their hearts were damaged. After reviewing a number of men with apparent cardiac disabilities associated with malnutrition he concluded that while they had some signs of thiamin deficiency, these were not then progressive, and that most of their debility was due to general causes and not to a specific dietary defect. There was always a remote possibility of cardiac manifestations appearing without warning in the subjects of any type of beriberi, but on the other hand, numbers of Dutch patients from Java were treated at Nakom Paton with severe beriberi, and though they required massive doses of thiamin to relieve their symptoms, at no time did they show any signs of cardiac disease.

These observations made in several Japanese prison camps in widely separated areas are of great interest. They illustrate how important it is to be sure whether circulatory symptoms are due to true cardiac affection or not. In the original state of these men there were disturbances of cardiac function, yet when the associated general conditions were relieved they made good recoveries in spite of the fact that the thiamin level in the diets of the hospital areas was still subnormal, though higher than the levels previously available. The opinion of these investigators that the majority of the men's residual circulatory symptoms were due to neurocirculatory asthenia is surely correct, and has saved considerable unnecessary invalidity. This opinion was later reinforced by the medical officers of the 2/14th Australian General Hospital, which was sent to Singapore as the medical wing of a prisoners of war reception unit. In the course of their work they reviewed 1,230 men who had been in Japanese prison camps, and in routine radiological examination of the chest the radiologist noted the occurrence of cardiac enlargement. Only in some twelve instances were radiological evidences of enlargement of the heart found. Most of these were explained by some circulatory condition, such as hypertension, and only three were considered to be possibly due to deficiency diseases.

Cardiac emergencies fall into quite a different category. In a settled area like Changi camp opportunities arose to study these alarming and often fatal attacks. Occasional cases were seen in 1942, but when the men began to return from the railway working camps more appeared in "F" Force, especially during the last six months, when deterioration of the troops was evident. Sudden death without warning occurred occasionally. This was seen both in working camps and in more settled hospital areas, and frequently in men not previously regarded as ill or at most as mildly ill. Apparently this sudden cardiac arrest was due to rapid and complete breakdown in the conducting mechanism of the heart, in other words, unexpected heart-block. Less dramatic, but probably of identical cause, were the attacks of temporary ventricular arrest which were occasionally seen. Some patients recovered after many such attacks, others died after

a variable number. Adrenalin, preferably injected into the heart, terminated these attacks if given promptly, and careful watch was kept on men who had suffered such a seizure. The signs and symptoms were those of the familiar Stokes-Adams attacks. Some patients died in bed; in these exertion could not have been a factor. Hunt, quoted above, thought that exertion played a part in those deaths seen among his patients, but the conditions there were much more unfavourable and severe. Post-mortem examination revealed no evidence of coronary disease, the heart was pale, especially in muscle nearer the endocardium, and no oedema was present. The right ventricle was often dilated without apparent cause. The cause was thought to be beriberi with other added factors such as anaemia and other nutritional defects. Malaria and dysentery seemed in some instances to have some predisposing influence. It is perhaps significant that beriberi appeared in Changi one month after the capitulation in 1942, and was relieved only when Red Cross supplements arrived in October 1942. The first sudden cardiac death occurred at the end of March 1942. It was early recognised that if beriberi was the cause of these cardiac emergencies, it was curious that no other systemic manifestations of this state were usually evident. Though no observations were made suggesting that diphtheria might be a likely contributory cause, it is one always possible. In 1943 diphtheria was rife for a time on Singapore Island in some of the camps, the cutaneous type was common and a considerable number of neuritic complications occurred. But among over 100 patients no cardiac complications were found, other than tachycardia in three cases. There is thus no evidence that these emergencies bore any relation to a diphtheritic infection.

4. *EFFORT SYNDROME*

Officially the diagnosis of "disordered action of the heart", so common in the 1914-1918 war, was discouraged. Even the less objectionable "effort syndrome" and "neuro-circulatory asthenia" were considered undesirable. In the Middle East fixation neuroses were not uncommon, but only a few involved the circulatory system; somatic symptoms much more frequently fixed on the digestive system. Fitts and others pointed out that one factor in this was the lessened physical strain on the soldier of 1940 as compared with that imposed in 1914-1918. Physicians recognised, too, how much harm could be done by directing attention to harmless physical manifestations of anxiety or fatigue. In 1940 the Royal Australasian College of Physicians, following a discussion on "The effort syndrome", made some recommendations to the Director-General of Medical Services of the Army for his information and help. These were designed to prevent neurotic incapacity similar to that produced in the previous war by a false assumption of organic damage of the heart. In October 1940 a suggestion was made by several physicians with the A.I.F. in the Middle East that a centre should be formed, preferably at a convalescent depot, to which Australian patients with "effort syndrome" could be sent. Even in this suggestion there was some echo of the teachings of the 1914-1918 war, but the objections to the usual diagnostic labels were realised. Later

Brigadier Burston, D.M.S., A.I.F., proposed that this syndrome should be officially known throughout the British forces as "temporary neuro-vascular debility", so as to avoid any suggestion of a permanent malady. However, the numbers proved to be few: some instances were seen in Palestine and Malaya, but the problem was never of sufficient importance to warrant special action.

In 1942 the position became rather different. War threatened the Australian mainland, and the Australian forces were engaged in tropical battlefields of peculiar difficulty. As pointed out in the section on psychiatry the proportion of cardio-vascular neuroses increased considerably in men fighting in these jungles, mountains and marshes. Anxiety states with various fixations became common also on the mainland.

A technical instruction was issued in which the importance was stressed of not ascribing symptoms to the heart except with sound reasons. In this it was stated that

"in a man who has been badly shaken by warlike operations a group of visceral sensations is experienced, cardio-vascular, gastro-intestinal and nervous, and the syndrome which becomes fixed in the ensuing neurosis depends largely on suggestion or on what particular form of disease he is most afraid of".

Medical officers were warned to avoid any suggestion that these symptoms may be due to heart disease, and directed not to label such men as suffering from any of the synonyms of "D.A.H." or even "neuro-circulatory asthenia". It was further stated that there was abundant evidence that even severe and prolonged exertion could not damage a healthy heart, and the grave disservice done by a false diagnosis of heart disease was stressed, the more grave since the harm once done cannot be fully eradicated. The only name officially permitted for use in evacuation to hospital was "N.Y.D. debility". It will be observed that even this tentative diagnosis is subject to the drawback of all "N.Y.D." diagnoses, with their inherent mystery without which many psychosomatic disturbances would perish of inanition. The strikingly infectious nature of these conditions was well illustrated in an outbreak of cardiac neuroses in a camp for Italian prisoners of war in Australia. A man who had suffered a slight muscular strain of the chest wall while digging was sent to bed by the Italian medical officer as suffering from a cardiac injury, and a characteristic neurosis of the "effort syndrome" type resulted. This was followed by a stream of similar cases. All the men presented the classic picture of cold bluish extremities, with pain in the centre and left side of the chest following exertion. They all belonged to one compound, while other compounds which were served by different medical officers had no men so affected.

More interesting still is the series already described among the men of the 8th Division while prisoners of war. These observations demonstrate how correct measures of full investigation and reassurance can be effective even in the face of risk of serious organic disease and disability. The same important principle emerged in the handling of typhus fever. To most medical officers the clinical manifestations of scrub typhus were a new field. The extreme prostration and serious condition of those severely

attacked, and in particular the post-mortem evidence of an intrinsic myocarditis caused a fear state to arise lest these changes should be permanent. The question has been dealt with in the section dealing with typhus, but it should be noted that in Australia as in other parts of the world a cardiac neurosis based on an attack of typhus could easily be produced.

5. *ANOMALIES OF RHYTHM*

Disturbances of rhythm *per se* have not been important in medical services. Extrasystoles were more frequently observed in conditions of exhaustion and malnutrition, but they have been but part of the clinical picture. In other respects this common form of irregularity was no more significant than in civilian practice. More important, though uncommon, were occasional instances of temporary bursts of disordered rhythm, particularly paroxysmal tachycardia and paroxysmal auricular fibrillation. These presented an occasional problem, especially when the patient held a responsible post. Full consideration of all the circumstances solves these problems. In one instance an officer with an important command had a paroxysm of fibrillation lasting several days, but his history was favourable, so he was permitted to carry on and did full service of an active kind for several years without further trouble. The more sinister attacks of the Stokes-Adams type seen in prison camps have been already described.

6. *DEGENERATIVE VASCULAR DISEASE*

The diagnosis and prognosis of degenerative vascular disease were often important in the work of medical boards, and in base hospitals, especially in assessing the condition of men in the higher age groups. These problems were much those of civil life, except that the possible physical demands on even senior officers could not always be foretold. Following current practice full investigations were more often called for, and as these inevitably included electrocardiographic examination, the question of supplying electrocardiographs to military hospitals arose. In 1940 General Downes, then D.G.M.S., ruled that hospitals going overseas would not take electrocardiographs, but sometimes private gifts of such equipment were made to individual medical officers for this purpose. With the establishment of base hospitals there was a greater demand for cardiographic tracings, and eventually an Australian type of electrocardiograph was issued to all Australian general hospitals. Climatic difficulties in the islands offset somewhat the value of this sensitive equipment, and maintenance offered difficulties. After a time a further difficulty arose that a diagnosis affixed to an electrocardiogram sometimes carried more weight in a patient's history than was warranted. Technical Instruction, No. 87, was therefore issued which stated that:

"It is undesirable that a diagnosis of myocardial or coronary disease should be made on the evidence of an electrocardiogram alone" and that "No diagnosis of a clinical condition will be made as part of the electrocardiographic report".

7. *OTHER CONDITIONS*

Among the rare events may be mentioned a few cases of unexplained cardiac failure. For example, a well-nourished man with no relevant history was admitted to hospital with increasing breathlessness, ascites and oedema, and after a brief illness died of heart failure. Autopsy showed that the failure was, as clinical events indicated, conspicuously right-sided; no cause was found. There was no evidence of rheumatic heart disease or diphtheria, or of coronary disease, or of sclerosis of the pulmonary blood vessels. Such events are described in contemporary literature and indicate the difficulty inherent in assessing cardiac disease. A few rarities such as temporal arteritis were seen. Other conditions do not merit special mention, except the importance of arterio-venous aneurysm in producing circulatory failure. Numbers of these lesions were produced by war injuries; the difficulties involved in complete cure are described in the surgical section of this volume. It is perhaps not irrelevant to point out here the physiological difference between the work imposed on the heart by voluntary muscular exertion even of the severest type, and that made necessary by the exigencies of maintaining a constant efficient circulation against an undue and inescapable load.

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CHAPTER 24

CHRONIC RHEUMATIC DISEASES

MEDICAL officers conducting sick parades have remarked that the war was one of backs, heads and stomachs. This has its parallel in civil life. The rheumatic diseases have been, and still are, stealthy robbers of man-hours in industry, and before the 1939-1945 war were estimated to cause one-sixth of the total invalidity of Britain. In the armed Services acute varieties of articular rheumatism were uncommon; likewise certain other forms such as rheumatoid arthritis and degenerative arthritis. Nevertheless other members of the vague categories of chronic rheumatic disorders had a high nuisance value, especially among troops under training, and large numbers of men were started on the way that leads to successive medical boards, with the inevitable end result of discharge. No useful statistics can be given owing to the wide disparity of diagnostic labels, with their frequent lack of a sure pathological basis. The differing systems of classification used by the services, and unhelpful methods of consolidating figures relating to diseases affecting bones, joints and connective tissues make statistics of little value. Yet every sick parade, particularly of troops resting or under training, or those employed in base areas, had its quota of men complaining of discomfort in the trunk or the limbs; every medical board encountered many others, and every medical unit holding patients had numbers of men to deal with for rheumatic disorders.

In this vague generic term are included the infective and post-infective groups of arthritis, or more accurately as a rule peri-arthritis, degenerative and post-traumatic affections of joints, and non-articular rheumatism (fibrositis and myositis so-called). In addition there were special conditions of varied aetiology, which include the sciaticas and lesions of the intervertebral discs. Of these the most vague and least serious types caused in the aggregate by far the greatest inroads into manpower.

ARTHRITIS AND PERI-ARTHRITIS OF INFECTIVE ORIGIN

The articular complications of some infective diseases are well known. In the section on bacillary dysentery such sequels are described; there are sound reasons for attributing these to infection, and in some cases at least, to a still active infection. Painful areas, apparently in the region of muscular or fascial tissues, could occasionally be demonstrated during convalescence, and firm tender nodules could sometimes be felt. In other infectious diseases there was some presumptive evidence of a causal relation between infection and similar lesions, but the grounds were less definite. A few instances were seen of febrile illness of undetermined nature associated with pain, heat and swelling of one or more joints. One such series was observed in Libya. Several men in one battalion were attacked within a short period, and were unable to carry out military duties for a time; the condition tended to become subacute, though complete resolu-

tion took place. In 1942 there was an outbreak of peri-articular rheumatism among servicemen and women in South Queensland. In one month twenty-five patients so affected were admitted to one hospital alone. The cause was assumed to be of infective nature. The so-called Reiter's syndrome exemplifies a similar connection with infection.

Though not directly related to infection, it is convenient here to mention the subject of post-inoculation phenomena in relation to rheumatic disturbances. Michael Kelly has reviewed the literature on post-injection neuritis and has presented some presumptive evidence of a connection between the immediate reactive effects of inoculations and the possible sequelae. In the absence of proof of any causal relationship between inoculation reactions and rheumatic affections of connective tissues the question cannot be further pursued here. The importance of protecting an army against serious infectious diseases must come first, though it may be agreed that it is desirable to produce reactions as little violent as possible within the limits of adequate prophylaxis.

POST-TRAUMATIC AFFECTIONS OF JOINTS AND RELATED STRUCTURES

These more often were of a surgical nature, but degenerative changes sometimes began after injury, depending on factors such as local blood supply or age. In general the effect of trauma was often of importance in many of the chronic rheumatic conditions. It can better be dealt with under the heading of muscular and connective tissues. Degenerative changes in or about a joint were of importance in the aging groups. Osteoarthritis, and in particular spondylitis, was seen in some of the older men, either as a spontaneous or accidentally recognised lesion, or in relation to trauma.

In the absence of accurate figures, no estimate can be given of the frequency of ankylosing spondylitis in the Services. It seems safe to assert that as time goes on it will be found to be less uncommon than was thought. Too often spondylitis is thought of in terms of a radiograph with more or less spectacular osteophytes, which may not be causing any trouble, whereas *spondylitis ankylopoietica,* a disease *sui generis,* may easily be overlooked. Medical officers occasionally saw men of the second, third or fourth decades, with backache, some appearance of exploiting an exaggerated complaint, and discomfort in the chest or pelvic girdle. In the early stages, before the clinical and radiological pictures are clearly established it would be easy to do such men injustice.

FIBROSITIS AND MYOSITIS

Some writers question the independent existence of "fibrositis" or "myositis" as a rheumatic lesion, but it seems justifiable to classify it as distinct from the articular and peri-articular types of rheumatism. It is perhaps wise to point out that the use of such terms as "fibrositis" is made with the reservation that it is understood that the tissues affected are not necessarily fibrous tissue. Copeman and others have shown that con-

nective tissue may herniate through fascia, forming nodules, chiefly composed of fat and areolar tissue. These herniations are often intimately related to nerve fibrils, and there are good grounds for believing that they may give rise to irritation and discomfort. Of course the demonstration of nodules alone does not prove the presence of an active rheumatic lesion.

Of the possible causes of soreness and pain in deep muscular or connective tissues, for instance in the common site of the paraspinal regions, we may consider infection, injury and cold. Infection has already been mentioned. Injury does not necessarily mean one sudden or severe traumatic act; it may be repeated, even though not actually severe. During the retreat from Greece and Crete many instances were seen of men, particularly walking wounded, who suffered from pain and soreness in the limbs and back. The muscles and related structures were tender, but after rest, and in spite of an undoubted related anxiety, they made a good recovery. Men subjected to fatigue, especially in very cold weather, as during the winter in Libya or Syria or Greece were particularly prone to such troubles. Rapid changes of temperature together with exposure were conditions most likely to be found in front line service.

PAINFUL BACK

It will now be best to consider the subject from a regional point of view, and discuss the causes of painful back so common in the Services. In the Middle East large numbers of these conditions were seen. Many of them were in the men rising towards the higher age limit and after a few months training in Palestine numbers of these were already in hospital. Often they had drifted from hospital to convalescent depot thence to base depots and back to inactive units as "B" class soldiers, only to start the round once more. Eventually some could not be further usefully employed and were returned to Australia. All through the war this was repeated on different fronts. Such patients' medical dossiers usually bore such diagnosis as "fibrositis", "myositis", "spondylitis", "lumbago", or "sciatica", or in a more agnostic mood, simply "low back pain". There is no doubt that these could be correctly regarded in most instances as psychosomatic states, with anxiety projected along the line of frequently produced symptoms. An interesting example of this psychogenic factor was observed in the 2/6th Australian General Hospital in 1942 just before the battle of El Alamein. Columns of troops of the 9th Division A.I.F. marched past the hospital on their way to the Sinai Desert and hence to the front. The effect of seeing these well trained and disciplined men was striking on some of the patients with backaches, who sought discharge from hospital and improved sufficiently to take some part in the events so inspiringly foreshadowed.

Later in the war this problem was still so troublesome, especially to young and comparatively inexperienced medical officers, that Technical Instruction, No. 32, was promulgated as a help in diagnosis and treatment of low back pain. In the patient's history the most important features

were the nature and duration of the pain, any relation to injury, any radiation to other parts, and the effect of rest or exercise. Obviously a check of the general physical condition was necessary. During complete physical examination opportunity could be taken to observe freedom or restriction of movement, posture, symmetry, evidence of wasting or muscular spasm, or deformity. Movements of extension and flexion were tested, any tender spots noted, particularly with regard to consistency of complaints. If there was no evidence of lesion the soldier could be reassured, and not sent to hospital. X-ray examination was ordered if thought advisable, and interpreted with fairness and caution. The medical officer was warned that mere postural conditions did not contraindicate work, but spondylolisthesis, bone injury such as compression fracture, and bone disease such as tuberculosis should not be forgotten. Examination should distinguish between affections of joints, muscles and ligaments, and nerves.

Captain D. Stuckey in a review of backache in soldiers laid stress on a thorough examination, and found it was advisable to measure the legs carefully. He found that most of the postural syndromes were associated with a difference in length of over ¼ inch, and that adjustment of boots was often advisable. The assessment of psychoneurotic factors was an important part of all initial consultations for pain in the back, but it was also essential to avoid bias and be alert to recognise the signs of organic disease, particularly important conditions like ankylosing spondylitis, or lesions of the sacro-iliac synchondrosis, or of the intervertebral discs. Treatment was largely concerned with the relief of symptoms precluding activity. It was found that admission to hospital, though often unavoidable, too often confirmed the condition. In the Australian forces there was never justification for the establishment of special centres where physiotherapeutic methods could accelerate recovery. At the same time, as Copeman has pointed out, there are uncomfortable conditions of the back and limbs which can be relieved to the point of permitting activity, and even if elaborate equipment is unavailable, extemporisation can supply most of what is needed. Most holding units could apply such measures, which were often effective, though it must be admitted that many patients with backaches were not keen soldiers nor desirous of rejoining their units, but anxious and readily confirmed in the easier, though more miserable, path of chronic ailment. Medical boards were faced with the problem of disposal of many of these; there often came a time when a man was found to be of no further value for active work. For some of these at least the cure lay in return to civil life. Hysteroid signs and symptoms were not very uncommon. Over-emphasis and exaggeration of symptoms were common. Peculiar postures were often seen, and hysterical fixation of the spine was not very rare. Occasionally remarkable degrees of kyphosis were seen, with a strange tortoise-like out-thrusting of the head. True muscle spasm was uncommon, even in these patients, who attracted unjustified sympathy, and thereby confirmed fixations in others.

Local injection of anaesthetic agents was often found valuable, both from the diagnostic and therapeutic points of view; combined with a

degree of rest, deep massage, heat and exercise it could initiate improvement. This method was of value for the treatment of painful foci, such as nodules. A question of some importance was how far these chronic rheumatic lesions should be handled in orthopaedic and other special clinics or hospitals. In Australia a certain amount of centralisation took place, though not to the degree practised in England and America, where of course the numbers involved were so much greater. Some physicians felt that in view of the importance of psychosomatic aspects of some chronic rheumatic states, patients needing hospital treatment should in the first instance be under non-surgical surveillance. Certainly one difficulty in the treatment of these conditions in orthopaedic hospitals or wards, was that inevitable contacts with patients suffering from long term disabilities of bones or joints produced an environment unfavourable to quick recovery. It will be seen that there is a psychological problem very similar to that of the "ulcer-type" patients, who must be investigated if doubt exists, but who are readily confirmed in an invalidity whose basis is only in part, and perhaps in small part, organic. For the solution of the problems raised by the subjects of chronic rheumatism, a close liaison between hospitals and convalescent depots was necessary. Greater care and thought in attaching a diagnostic label to men reporting with a complaint of pain or stiffness in the trunk or limbs were and still are even more necessary. A diagnosis of articular disease may be made when a strain of related muscles may be the only lesion; or the dragnet term "fibrositis" may be used without any justification. It is very hard to retrace the steps of such diagnosis without pathological basis. Finally, without presenting statistical evidence of the relative frequency of the various physical and psychological factors of causal importance in "rheumatic" disorders, these states caused a great amount of wastage in the Services during the war, just as they did in the industrial world before the war, and still do after it.

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CHAPTER 25

DYSPEPSIA

SOME surprise has been expressed at the importance of digestive diseases in the Services, but surprise is hardly justified in view of the increasing number of dyspepsias in the civil community before the war. Even before the 1914-1918 war, an experienced physician analysed the presenting symptoms of patients attending a large medical outdoor clinic and found that the predominant symptom was abdominal pain. In the last generation there has been a conspicuous increase in the number of young men with duodenal ulcer. In speculating as to the causes of this increase in the ulcer-type dyspepsias, physicians have blamed the altering pattern of life, particularly in relation to mental strain, changed habits of eating, different kinds of food, dietary deficiencies, dental inadequacy, and increased general consumption of alcohol and tobacco. No doubt greater accuracy of diagnosis has swelled the numbers too, but the increase in dyspepsias has been greater than the rise in the proven ulcers. Perforation of peptic ulcers is a more common emergency of recent years, and it was not uncommon during the war, especially at certain periods, and under certain conditions, for example, in civil communities exposed to frequent enemy attack.

It has been pointed out that tobacco became a compelling and almost universal addiction during the war years, and this has been cited as an important cause of dyspepsia in servicemen and others. Tobacco used in excess is generally regarded as an activator of active peptic ulceration, but it seems likely that heavy smoking and peptic ulcer are both associated with a certain personality pattern. Persons of this type are perhaps not likely to heed Jowett's injunction concerning smoking, "Do not set up for yourselves new necessities". It is conceivable that all the causes mentioned above may play some part in the production or maintenance of dyspepsia. If the manner of our life is, in part, responsible for increasing the burden on digestive function and in particular on the autonomic nervous mechanism involved, it is likely that the conditions of military service will not in any way lighten this burden, but rather add to it. It further seems likely that whether such a burden will be of significance or not depends largely on the mental make-up of the individual.

It is not easy to dogmatise about the importance of battle stress in producing dyspepsia. There are so many variables, such as the types and ages of men involved, the diet available to them, the conditions of daily living, climate and hardship, that parallels cannot be drawn. Stress as an added factor sometimes seemed to be significant: thus after the trying events of Greece and Crete digestive troubles were found to be more common in some units.

Doctors in their views on dyspepsia, perhaps do not always have the same viewpoint; some lay greater stress on the food the patient takes, and when he takes it; others are more concerned with the peripheral nervous

and secretory mechanisms of digestion, while others lay greater stress on considerations of life and its assault on the nervous system. Even by the most balanced observers bias is hard to avoid, and this reflects on statistics. This was evident in studying the administration of different service hospitals. In one, a relatively high proportion of patients classed as "functional dyspepsia" would be found, in another there would be a correspondingly high number of men classed as suffering from "anxiety neuroses, with digestive fixation". In the former all such patients were usually admitted to a "digestive" ward, in the latter this was largely avoided. It is probable, therefore, that the statistics are not trustworthy in this respect.

In the Middle East the rates per 1,000 for digestive diseases and, by comparison, for infectious and parasitic diseases were as follows:

	1940	1941	1942
Digestive . . .	196.87	192.80	144.98
Infectious and parasitic .	275.00	298.14	219.67

The percentages of men with digestive diseases among those returned to Australia unfit from the A.I.F. in the Middle East were as follows: 1940, 19.54 per cent; 1941, 12.68 per cent; and the first quarter of 1942, 14.66 per cent.

In convalescent depots the numbers of men recovering from dyspepsia were practically identical with those recovering from infectious diseases. In the Australian force in the United Kingdom, in 1940, the incidence of digestive diseases was relatively low, only 81.4 per 1,000.

Coming to the clinical aspects of digestive disease in the armed forces there are certain generalisations that may be made. Soon after the arrival of the 16th Brigade in Palestine the number of dyspeptics with a past history of indigestion was noted to be considerable. This history was all the more evident in the case of men who had a declared ulcer. The importance of this was recognised, and representations to Australia caused the inclusion of an enquiry concerning digestive disturbances in the *questionnaire* answered by all recruits. The discovery of an abdominal scar led to enquiries also, and as a general principle men with a history of operation for peptic ulcer were not accepted for active service. Had this been more rigorously followed, it would have been preferable, as the very instances in which exception is made are often those of men whose responsible jobs are provocative of recurrence. A man with an active ulcer is often a problem behind the desk of a civil administrator, and this problem is likely to be accentuated by wartime responsibilities. Yet there were specialised duties that could be discharged well by men with an ulcer history. Numbers of men in the air force, for example, could carry out technical work in sheltered occupations as well as in civil life, though the percentage of discharges for digestive diseases from this service reached as high as 17. Though flying stress often caused recrudescence of symptoms, it did not seem to bring about acute complications such as haemorrhage or rupture.

Soldiers with an "ulcer type" of dyspepsia often had long histories of digestive trouble, with a characteristic record of exacerbations and remissions. Those with dyspepsias conforming less closely to the conventional ulcer pattern, also often had a significant history. Usually they complained that they "could not eat the army food", and often stated that they had been used to a special diet in their own homes. It would seem that a *questionnaire* for recruits' wives or other female relations would reveal some interesting information. It is probable in any case that men whose patterns of life contain a component of a special diet, whether for an organic or non-organic dyspepsia, have also a special personality pattern, which is often not very adaptable to a new environment, particularly that of the curiously restricted communal life of the Services.

One generalisation which caused some surprise at first, was that a high proportion of the dyspepsias seen were due to gastric or duodenal ulcer. This is supported apparently by the findings of all armies on all fronts. Without being able to present accurate figures, radiologists with a wide experience of pre-war hospital work thought that a higher percentage of ulcers was found in the X-ray departments of the services in the field, than in those of civil hospitals. This, if true, might be due to the higher degree of clinical selection of patients sent for X-ray examination of the digestive tract in the armed forces than in civilian out-patient clinics, where patients may attend largely for their own personal satisfaction. The acute accidents, perforation and haemorrhage, were extremely uncommon in the Australian Middle East force.

With regard to complaints about food, it must be admitted that service dietaries often looked better on paper than the prepared food looked and tasted. Greasiness of food was often complained of, and not always unjustly. Inspections of food at meal parades were not always critically carried out. The development of the Australian Army Catering Corps at a later date played a very important part in improving the quality and palatability of food as presented to the soldier.

One clinical feature of the ulcer dyspepsias in the Middle East was the prevalence of a complaint of vomiting. This was not always proved by observation, but such a history was common. Classical time relation between eating and the onset of pain was not always seen, though this but conforms to civil experience. It may be remarked that abdominal pain associated with indigestion does not arise only from the stomach and duodenum. Convincingly characteristic histories were sometimes given by men who gave no other grounds for a diagnosis of ulcer. In a certain limited class of men there was evidence that the appropriate history was used in an attempt to outwit medical boards. Indeed there is evidence that the dissemination of knowledge in convalescent depots was well organised in these circles. Loss of weight was also a common feature, due apparently to the limitation of food intake by the patients themselves as a form of self-treatment. Monotony of diet was also a cause, as the "light" diet or "ulcer" diet of most hospitals has little variation. Attempts were made to overcome the meaningless prejudice against all but "white" meats,

but even when a wider range of suitable food was introduced the patients were sometimes reluctant to take an increased diet to their own advantage. The diagnosis of "gastritis" or "duodenitis" was sometimes made, though the basis was not always convincing. The opportunities for gastroscopic investigation were naturally extremely limited.

Duodenitis was a diagnosis based on radiological findings. These were chiefly a diffused irregularity of the rugae, and spasm without a focal lesion.

In the early days of the A.I.F. in Palestine, supplies of some drugs were restricted: one of these was barium sulphate. This led to strict rationing of opaque meals, and cholecystograms were also restricted. A limited supply of films during practically the whole of the war period laid greater emphasis on the accuracy of fluoroscopy, which was in turn limited to some extent by the ordinary safety precautions against radiation. Stricter scrutiny of patients submitted to X-ray examination was therefore necessary. This insistence on thorough clinical methods was good in many ways and was a check on the referring of patients for X-ray examination without sound reasons. In some patients the carrying out of a barium meal had a valuable therapeutic effect, but the propriety of so using this method of investigation is open to grave abuse, as well as being very unfair to hard worked radiologists who are exposed to radiation hazards. Tests for occult blood and fractional gastric analyses perhaps assumed a position of rather higher importance as confirmatory methods, though the findings of the radiologists if "positive" were still a pivotal point of a diagnosis. This was particularly so when a medical board had to arrive at a decision about a man's fitness to perform certain tasks, or indeed any tasks in an armed force.

The preponderant type of established ulcer was duodenal. The recorded figures show a ratio of at least 5 duodenal ulcers for each gastric ulcer, though their diagnostic accuracy cannot be guaranteed, and they are not fully representative. Contrasting with these were figures published by Cleland in 1942 relating to civil experience. Out of 5,070 autopsies in South Australia he recorded 110 gastric ulcers and 70 duodenal ulcers. Gastric ulcer was four times as common in men as in women, and duodenal seven times.

When the A.I.F. returned to Australia and the A.M.F. were dispersed over wide areas the problems of digestive disease increased, both in base and field hospitals and in forward areas. The patients with persistent symptoms eventually reached base areas and were studied there in large numbers. Once again there was a danger of a spate of men pouring into hospital for full investigations which were sometimes justified by the history, and sometimes not.

Technical Instruction, No. 9, was issued dealing with the care of the dyspeptic soldier (see appendix). In spite of this, many men were seen in base hospitals in every capital city with unduly magnified symptoms. Even when a diagnosis was made at the base the disposal of the man was often difficult, particularly in one type of dyspepsia common about

1943-1944, the psychogenic type, a neurosis with somatic fixation. These men were best dealt with in ordinary medical wards. Unfortunately some of them even when returned to "B" class work reappeared in hospitals, where investigations were often made *de novo*. In one convalescent depot in 1942, out of 43 men with dyspepsia, 11 were found to have had multiple investigations. The immediate military prognosis was not very favourable for such men. Though in this early period of the Japanese war men were regraded to "B" class and given appropriate work in a base area wherever possible, many of them were not very useful, and eventually were discharged.

There was no doubt about the importance of emotional factors in the majority of cases of dyspepsia. Whether these factors were induced by the mental "let-down" of boredom and dull routine training, or by overwork and loss of sleep, or by combat stress, or non-adaptation to the conditions of service, or domestic or financial anxieties or repressed resentment, they frequently played a part not only in causing the indigestion but also in perpetuating it.

In 1943 Lieut-Colonel H. R. Love analysed 358 patients in Heidelberg Military Hospital. Out of 15,380 patients admitted 908 had dyspepsia. He found that 68 per cent had a history of digestive symptoms extending back before their enlistment. The commonest complaint was abdominal pain, which was present in 90 per cent; 20 per cent had vomiting, 3.6 per cent had heartburn, and 53 per cent had lost weight. The pain was continuous and usually most troublesome after meals or else not specially related to food. A clinical history was taken of all these patients, a special *pro forma* being used; and fractional test meals, tests for occult blood in the faeces, and barium meals were carried out and recorded. No organic abnormalities were discovered radiologically in 66 per cent. The percentage of ulcers found were as follows: gastric ulcer 4.7 per cent, duodenal ulcer active 7.2 per cent, healed 2.1 per cent, and irritable duodenum 8.5 per cent.

Love concluded that the fundamental basis of most dyspepsia in this series was psychic, but not "neurotic" according to the usual connotation of this term. Perhaps this accounts for the uneasiness felt by some medical officers in handling this variety of psychosomatic disease, seeking a mean between the extremes of fearing to "miss" an ulcer or dismissing the man as a "poor type".

The experiences of the medical services of the 8th Division, A.I.F., were of particular interest. They are dealt with in some detail because of the unusual circumstances attending all diagnosis and treatment. In Malaya during the early training of the 8th Division the problems of digestive disease corresponded closely with those of the A.I.F. in the Middle East. The same frequency of dyspepsia was observed, and the same difficulties were found in disposal of these men, always more troublesome in an oversea force than one training at home. During 1941, the great majority of dyspeptics complained of symptoms which had been in existence before their enlistment. The impression gained from the physicians in Malaya was

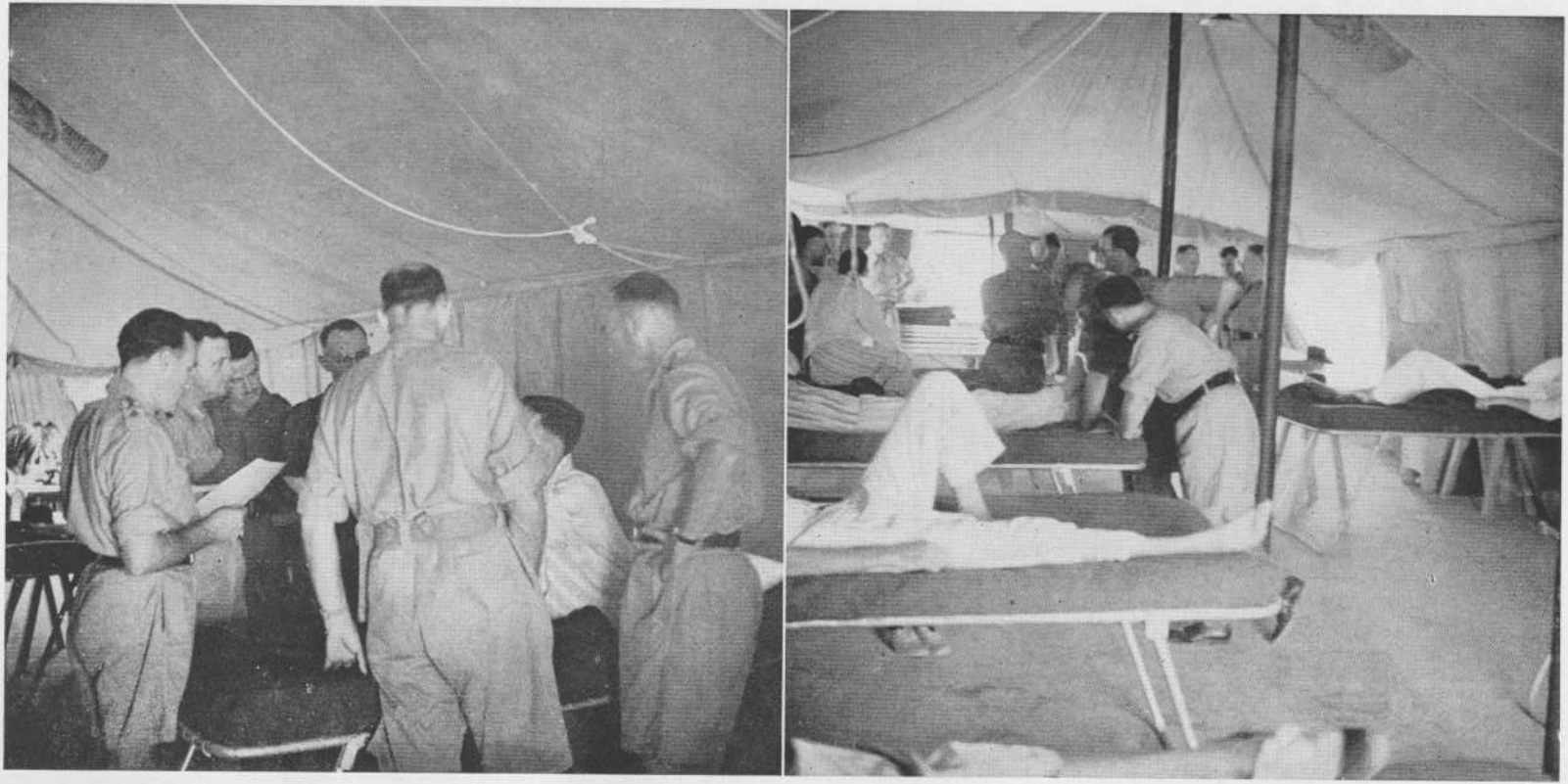


Likely breeding place for sandflies—Palestine.



(Australian War Memorial)

Western Desert underground C.C.S.: vectors of relapsing and sandfly fevers were found in parts of the desert.



Clinical meeting, Middle East, 1940.

that the proportion of organic to inorganic dyspepsias was low. No instance of perforation was seen in the force during 1941, and bleeding occurred in only three patients. The only patient requiring surgery was a man with carcinoma of the stomach. The majority of dyspepsias were believed to be psychogenic in origin, a belief supported by the common finding of a history of previous mental or nervous instability. In one series only 25 out of 177 barium meal examinations revealed an ulcer. From February 1941 to February 1942 of 85 patients boarded for dyspepsia 31 had peptic ulcer and 42 nervous dyspepsia. Up to this point, full diagnostic facilities were available, but with the capitulation of the force in Malaya the conditions were different in every way.

Immediately after the Japanese occupation began a series of men was seen with ruptured ulcer. Five such emergencies were seen in the Combined General Hospital on Singapore Island in a short space of time, but during succeeding months this "accident" was very rare. W. A. Bye in a special report on the work in the prison camp at Changi points out that X-ray studies were greatly limited, and after September 1942 no films were available. Barium was limited in supply, but till late in 1944 screening was possible. Of forty selected patients eighteen had active ulceration. Tests for occult blood and fractional test meals were possible, with the use of ground rice, till later the reagents were exhausted. A reasonable bland diet was devised for dyspeptics; its basis was milled rice, with additions from limited supplies of reserve rations, and from Red Cross stores that arrived in September 1942. Condensed milk, cereals and eggs were available during 1942, but in 1943 the ulcer diet deteriorated greatly in quality. Necessity demanded the use of unsuitable food in order to yield enough calories and vitamins. The fish and vegetables available were tough, but later a suspension of soya bean was added. At the end of 1943, many sick men returned from the Thailand camps, and all eggs and milk were perforce diverted to them. This left for the dyspeptics a monotonous diet of pap with limited flavouring, rather unpalatable supplements of vegetable oil and a small amount of fresh meat supplied by the Japanese in 1944. During 1944 calorific necessity compelled men with ulcers to eat black beans and milled maize as in the standard ration. Attempts were made to give these men a reasonably suitable diet in their own units, but this was too often impossible. The monotony of the food made the use of vivid condiments necessary, and this, added to the tough nature of the food, induced relapses of peptic ulcers to such an extent that some patients spent almost the whole of their term as prisoners of war in hospital. It was most important to ensure that only men with organic dyspepsia should be held in hospital, lest the numbers of gastric neuroses should grow unduly. Great care was exercised in the diagnosis by clinical and accessory means. As time went on occasional surgical complications occurred, and at Changi by the middle of 1943 pyloric obstruction had been recognised in three patients who were operated on with satisfactory results. By this time it was evident that the practical certainty of relieving most ulcer patients of their symptoms by medical means was an unattain-

able goal under prevailing conditions. Therefore from August 1943 to August 1944 nineteen men were submitted to gastro-enterostomy or partial gastrectomy with three deaths and excellent results in the remainder.

Mention has been made of a number of men who had perforation of an ulcer in the early period of captivity. Up to May 1943 eight men had this complication in Changi, but none thereafter. All recovered after immediate operation. Haematemesis occurred in eight men also. In a series of 44 men seen in 1942-1944 who had proven ulcers, 26 appeared to have had their first symptoms arise in Malaya, the others had a previous history of dyspepsia. Proof of ulceration consisted of operation findings, the demonstration of an ulcer by X-ray examination and haematemesis. It seems probable on clinical grounds that many more men had ulcers, but proof was unobtainable. On clinical grounds, Glyn White reported that in Changi gaol in 1944, a decided increase took place in peptic ulcers. He and Cotter Harvey from the Combined General Hospital, also found that an adequate diet was hard to obtain; there were deficiencies in fats and vitamin *C*, and the chief source of fat, palm oil, was distasteful to the patients. An attempt was made to prepare a purified oil. Drugs were scarce, and magnesium hydrate derived from sea water in the camp soap factory was used as an alkali in treatment. This gave some relief, but in general, the response of patients to treatment was disappointing. Anorexia and vomiting were noted to be common, perhaps related in some degree to nutritional deficiencies. The combined hospital by the end of 1943 was holding many men with peptic ulcer. When liberation came in 1945 it was felt that many of these men had reached a condition irreversible under existing environment, and only relief from the hardships they endured saved them from complete invalidism at the least. At the other end of the line of working camps, long after the completion of the Burma-Thailand railway, the large hospital at Nakom Paton was set up in 1944 by the Japanese and here Major Fisher and other physicians were able to gather interesting data and make an enlightening record of three and a half years' work.

No radiographic diagnosis was possible there, but organic lesions were not diagnosed except on sound clinical grounds. Fractional test meals were carried out on all the patients needing investigation: hyperchlorhydria was invariably found in patients with a clinical diagnosis of ulcer. At the end of the war, 70 patients with ulcer were in hospital: most of these had come from Burma. Their ages ranged from 25 to 45 years; over half of them had a pre-enlistment history of dyspepsia, and a number of these had a previous ulcer proven by X-ray examination or laparotomy. Their treatment caused great anxiety, for suitable diet and drugs were unobtainable, and they suffered considerable pain. Rice pap with stew if this could be taken was the basis of the diet; milk when obtainable was added, even half a pint daily was a help. Tapioca gruel, sieved vegetables, eggs and occasionally fruit were given when available. Meals were accurately timed, and frequent feedings arranged. Alkalies were not always obtainable, but it

was striking how bicarbonate of soda, now largely discredited as an antacid, gave great relief when supplies arrived.

The question of surgery caused some anxiety and, having regard for the extreme difficulties of operative work mostly carried out with home-made material, surgery was restricted to emergencies. Only two patients died from peptic ulcer during the whole period, one from perforation and the other from uncontrollable haemorrhage. Such operations as were done were not satisfactory, as adhesions and obstructive sequels occurred, but this was not surprising in view of the local conditions and the long deterioration of the patients in the Japanese jungle camps. Operation revealed how formidable were the ulcers in these patients. Some of the duodenal ulcers were two or three inches in diameter, anchored by adhesions to surrounding tissues so friable and oedematous that handling was virtually impossible.

Many other patients were seen with dyspepsia considered not to be due to ulcer, and numbers of these were found to be achlorhydric. The administration of dilute acid gave them some relief. The acid used thus in treatment was obtained either from scanty stocks or from hyperchlorhydric patients undergoing test meal examination. The excess hydrochloric acid thus obtained from ulcer patients was also occasionally used as a flux for soldering.

The great help given by Red Cross food supplies was welcomed in all hospitals when and where the Japanese permitted a distribution.

The treatment of prisoners of war in Italy and Germany who had peptic ulcers, gave rise to considerable difficulty. White bread was usually unobtainable and these men had trouble with the coarse black bread. In fact in some camps a very high proportion of the men complained of indigestion from the bread. As in other prison camps patients with tuberculosis and severe dyspepsias were, of course, given priority for necessary foods when these were available from Red Cross parcels.

Review of the whole war shows that digestive disease was of great importance in all armed forces. The harsh experiences of the men held captive by the Japanese illustrate how an occasional or remittent lesion like a peptic ulcer occurring under reasonable conditions becomes a dangerous, permanent and progressive incubus when living is reduced to its lowest terms. At the other end of the scale it is seen how peptic ulcer recurs under the stimulus of conditions of service, less flexible than those of ordinary life, particularly to the sensitive or unadaptable types. Most frequent of all the dyspepsias of service life are those which are probably also the commonest in civil life, those of psychological origin. How many of these may cross the ill-defined "organic" border and show frank ulceration cannot even be guessed. It cannot be doubted that the 1939-1945 war brought up digestive disease as a difficult problem. In dealing with it in civil life some attempt can be made to resolve those factors concerned with life and its asperities; in military life this is difficult. Its prophylaxis cannot be dealt with here, for in addition to the physical and chemical questions involved there is the basic difficulty of fitting human beings

more aptly into a world which they are striving daily to make more complicated.

APPENDIX

Technical Instruction No. 9

1. The present method of dealing with soldiers who complain of digestive upsets is failing in several aspects.

(a) Men are remaining in hospital too long with resultant waste of beds.

(b) The long period of careful dieting and minute investigation to which they are subjected tends to set up a neurosis by encouraging them to believe that their symptoms must have an organic basis. (This view is sometimes implanted by the R.M.O. "The doctor thought I had an ulcer and sent me to hospital but they could not find it.")

(c) The hospitalisation of such patients tends to increase the total number of digestive complaints; neurosis is notoriously infectious.

2. On the other hand men with definite peptic ulcers are rarely fit for military service. As a rule such ulcers will be found to have been present before enlistment but the history was concealed. These men should be transferred at once to a Base Hospital with a view to early discharge.

3. In 17 per cent of cases investigated at the 115th G.H., definite radiological evidence of ulcer was found.

4. Dyspepsia has proved to be so important a military medical problem that it is essential for all medical officers engaged in clinical work to assume a correct degree of responsibility in the recognition and disposal of the various types of soldiers complaining of digestive symptoms. These men fall into several groups:

(a) Those whose history and observed condition point to gastric or duodenal ulcer, or other organic abdominal disease, such as chronic gastritis, hepatic cirrhosis, cholecystitis, etc.

(b) Those who are suffering from other systemic disease such as pulmonary tuberculosis.

(c) Those who have a true disturbance of digestive function without evidence of organic disease; important factors here are type and nature of food available, dental equipment, etc.

(d) Those whose trouble is essentially psychological.

5. It is most important that an attempt should be made as early as possible in the medical history of every man so complaining to form a tentative opinion as to the cause of the symptoms.

6. The handling of dyspeptics in the field.—Many of these cases are likely to be seen in training units. Here, and wherever service conditions permit, an effort must be made to make a tentative diagnosis, and causative factors, such as improperly prepared food, tobacco and alcohol should be recognised. The soldier's dental state must be noted in every case and steps be taken to institute or accelerate necessary treatment. It is emphasised that the extraction of teeth often accentuates, temporarily at least, the dyspepsia. It is well within the province of the R.M.O. in certain of the cases encountered to attempt to adjust such faulty conditions as may give rise to dyspeptic symptoms, including psychological factors, such as anxiety. The routine handling of men complaining of indigestion merely by parading them to receive doses of alkalies represents a failure to deal with the situation.

The M.O. must have adequate reasons for referring dyspeptics for consultation or investigation in hospital, and if he refers such cases he must forward an adequate history with the man. If important evidence is available, e.g., proof of vomiting, haematemesis, melaena, etc., it must be stated. In these cases a field diagnosis of indigestion is sufficient. It is most undesirable that a diagnosis of any organic disease be entered on the field medical card or that the idea of organic disease should in any way be suggested to the man. It is equally undesirable that the M.O. should inform any man that he is being sent to hospital for the purpose

of undergoing some specific investigation such as X-ray, since the final judgment as to such procedures rests with the specialists in hospitals.

7. Handling of dyspeptics in hospitals not equipped for full investigation.—Some assessment of each man's condition must be made as soon as possible. If it is considered that there is a good chance of returning the soldier to work after a short period of treatment he should be retained for such treatment and such limited investigation as may be possible or desirable. If it appears that further investigation and a longer period of treatment is necessary he must be transferred to a more fully equipped hospital as soon as practicable. In this case an adequate summary of history and progress must be sent with the man.

8. Handling of dyspeptics in fully equipped hospitals. Strict economy in investigation will be observed. Dietary systems should not be unduly elaborate. It is particularly desirable that men who are likely to return to duty should be given as full and varied a diet as is compatible with their condition, since it is easy to produce or confirm a dietetic neurosis in these men, even by the routine use of the so-called "light" diet, with its traditional obsession of "white" meat. Adequate discipline of these patients must be observed.

Where it is established that organic disease exists, and it is considered that for this or other reasons the soldier's disability renders him unfit for military service, medical boarding must be instituted as soon as his condition is reasonably stabilised.

(a) Dyspeptic ward in hospitals.

While it is advantageous to group cases of organic digestive disorders together for convenience of handling and dieting, the indiscriminate segregation in one ward of all patients admitted for investigation of dyspepsia is not to be permitted. It can do nothing but harm to many of these patients to confirm a digestive "fixation" which is often the result of some psychological stress.

9. Medical boarding of dyspeptic patients.—The following information should be available for the information of the Board:

(a) Report from R.M.O. containing original reasons why the patient was submitted for investigation, and also observed findings, etc.
(b) Record of the man's progress in hospital, with special reference to:
    (i) Presence or absence of symptoms or complaints.
    (ii) Physical findings.
    (iii) Substantiation of such signs as vomiting, diarrhoea, haematemesis, melaena, anorexia, etc.
    (iv) Results of special investigation, X-ray, test meal, etc.
    (v) Evidence of breaches of discipline, if any, e.g., excessive smoking, contrary to instructions, bouts of alcoholism, etc.
(c) A considered opinion of the man's condition written on the hospital record and signed by a responsible officer.

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CHAPTER 26

DISEASES OF THE CENTRAL NERVOUS SYSTEM

DURING the war little was added to organised knowledge of nervous diseases by the Australian medical services, but many clinical observations were made. The individual problems of diagnosis and aetiology were often difficult.

Nervous diseases appearing in service hospitals fall under many headings. These include such different groups as the following: system diseases as seen in civil practice; meningitis of non-suppurative type; encephalomyelitis of known or unknown cause, merging on the one hand into a purely cerebral and on the other into a peripheral affection; neuronitis and neuritis, single and multiple; nutritional states, such as spastic paraplegia as part of a deficiency syndrome; and symptomatic problems such as epileptoid seizures. It would be completely illusory to attempt to place clinical syndromes so diverse into aetiological categories. It is best therefore to refer to some of the clinical pictures seen and to suggest their possible basis.

THE FAMILIAR SYSTEM DISEASES

These need no extended reference. Occasionally men were seen with degenerative atrophic or dystrophic states, either non-existent in a recognisable form on enlistment, or else not detected. Occasionally, too, even medical boards, with the advantages of detachment and full-time work, as in the Middle East, had difficulty in deciding whether nervous signs and symptoms were of organic origin.

Though conversion hysteria was not commonly seen except in minor waves restricted both in time and place, it sometimes confusingly imitated organic lesions. Even more frequent was the combination of an organic basis and a large psychic element. (See section on psychiatry.) Now and then intracranial tumours occurred and even the rarities of neurological practice. One of the most unusual of the latter was an instance of *myasthenia gravis* associated with thymic enlargement, and relieved by surgical removal of the gland.

NON-SUPPURATIVE MENINGITIS AND MENINGO-ENCEPHALITIS

The most important varieties of these forms of meningitis and meningo-encephalitis seen on service were benign lymphocytic chorio-meningitis, and those associated with other virus diseases like mumps. These could as a rule be distinguished on clinical grounds, though this was not always easy in the early stages of mumps-meningitis when the characteristic glandular involvements were absent or inconspicuous. Differentiation by neutralisation tests was not possible with the facilities available at the time.

In most instances lymphocytic chorio-meningitis was also benign, and rarely affected any part of the nervous system but the membranes. Small outbreaks occurred during the warmer months of 1942. In Syria a series of thirteen cases was collected at the 2/3rd Casualty Clearing Station. No connection with animal vectors, such as mice, was observed. Headache was universal; onset was sudden, not infrequently with fainting. Neck stiffness occurred but not head retraction. Nausea and vomiting were common. The cell count in the cerebro-spinal fluid was usually 300 per cubic centimetre at the onset, and most of the cells were lymphocytes, even up to so high a percentage as 98. The acute illness usually lasted about a week; no focal signs were present in the nervous system, and recovery was satisfactory. Neutralisation tests were not carried out.

In men suffering from malnutrition, the disease was not always so benign. In Malaya, Harvey reported twelve cases occurring in 1942 among prisoners of war of the 8th Division. Three deaths took place in this series.

Lymphocytic meningitis was occasionally seen as a complication of mumps. There were usually some other features to be found on careful examination which settled the diagnosis. Fortunately serious involvement of the central nervous system was rare, so too were serious sequels. One of the most unfortunate occurred in a young Australian who on the fourth day of an attack of mumps had an ascending paralysis of the lower motor neuron type. Fortunately the staff of the 63rd British General Hospital in Cairo foresaw the risk of respiratory failure, and procured a respirator from the Anglo-American hospital in time to prevent his death from respiratory failure. Putting aside the question of aetiology this experience illustrated the need to have some form of mechanical respirator available; patients with threatened respiratory failure from a paralytic cause are fortunately very few in number, but their need is great.

Mention may be made here of torular meningitis, which was identified in several fatal cases in Palestine.

ENCEPHALOMYELITIS

Though no clear distinction can be drawn between viruses which chiefly attack the meninges and those preferring the central neural tissue, there are a number of conditions which can be roughly grouped under the heading of encephalomyelitis.

Certain tropical infectious diseases may produce confusing clinical pictures. Nervous complications are common in typhus and relapsing fever, and malaria and even dengue were occasionally misleading, but awareness and familiarity with the clinical pictures usually prevented diagnostic difficulties.

There was, however, a possible fallacy in assuming that nervous lesions found in a patient convalescing from typhus were due to this disease. This was well shown in a man in a base hospital who had peripheral palsies at first attributed to the typhus from which he was recovering, until it was found that he had been given one injection of diphtheria antitoxin for a membranous pharyngitis three weeks earlier. The probable reason for a

facial palsy was sometimes revealed by a history of several bouts of tick-borne relapsing fever. Double facial palsy in an endemic area was practically diagnostic of this disease. Further consideration of diphtheria as a cause of peripheral palsies will be given later. Fuller accounts of the nervous complications of typhus and relapsing fevers will be found in the appropriate sections.

The so-called infantile paralysis, acute anterior poliomyelitis, only needs passing reference here. Occasional infections were seen in the forces. Several cases occurred in a cavalry regiment in Cyprus in 1941: the men affected had fever with rapid onset of paralysis. In view of the greater number of young adults attacked during the more recent epidemics it is fortunate that more trouble was not experienced with this disease.

The so-called "diffuse encephalomyelitis" of indeterminate origin was occasionally seen. More clearly differentiated varieties such as the St. Louis or equine types apparently did not occur, though it is notoriously unsafe to dogmatise about the clinical types associated with different viruses. Therefore no attempt will be made to suggest that a presumed virus infection attacking the brain is necessarily different from one attacking the lower neuron. With this reservation neuronitis will later be described as an entity.

Diffuse encephalomyelitis produced varied pictures. A man died after drowsiness, muscular spasms, meningeal irritation, pleocytosis and increase in protein of the spinal fluid. Little but cerebral congestion was found at autopsy. Another soldier recovered with only slight sequels from paraplegia of unknown cause, with slight pleocytosis (200 cells) and excess of protein (80 mgm. per cent) in the spinal fluid. These two were included in a series of seven seen in six months by C. B. Sangster in a hospital in New Guinea. This series also included a hemiplegia of upper neuron type, with 65 cells and 85 mgm. protein in the spinal fluid, which gave a goldsol reaction of 3332211000. Another, clinically encephalitis, showed fever, lethargy and affective change, tremor, rigidity, drooping eyelids, and restlessness: cells in the fluid were high, 720, and the protein 160 milligrammes. One patient was under treatment for malignant malaria, but neither malaria nor typhus was considered to have any bearing on the condition. The remaining patients in this series had peripheral lesions, shortly to be discussed.

Other types of cerebral illness were seen, and ascribed to encephalitis. At the 106th Casualty Clearing Station, for example, at Finschhafen, within a short time a man died of acute ascending polyneuritis and another died after a brief, febrile illness in which acute mania was the predominant feature. No lesions except some evidences of diffuse encephalitis were found at autopsy. A third man three days after a febrile illness lasting ten days had a convulsion, followed by delirium and loss of consciousness. No abnormality was found in the cerebro-spinal fluid, and there was no evidence of malaria. Recognising the limited opportunities for investigation in the field, this small series may correctly illustrate

how acute disseminated encephalomyelitis may cause symptoms ranging from delirium to paralyses, central or peripheral.

Other patients were observed in whom cranial nerve palsies occurred; usually such lesions were not simply or singly focal, they were found on careful examination to be part of other changes in different portions of the nervous system. A distinctive type of encephalomyelitis was described in troops in the Northern Territory. Two men died from encephalomyelitis; the histological picture was identical and distinctive. Its chief features were focal necrosis of nervous tissues with accumulated polymorph or microglial cells, necrosis of the walls of the small and medium veins, which were infiltrated with inflammatory cells, and cellular infiltration with perivascular cuffing of adjacent nerve tracts. There was negligible meningeal reaction, and no evidence of any bacterial infection. The interesting feature of the condition was that in one patient the illness began with tenderness running from a small unhealed cut on one little finger which spread with pain up the ulnar nerve, and affected the whole arm. Later a rigor occurred and rapid spread of neural lesions was apparent. In the other patient cerebral symptoms occurred fourteen days after tonsillectomy; he had headaches, vomiting, and diplopia, and shortly before death, external rectus palsy. It would appear that the infective agent, which was not bacterial, reached the brain by peripheral channels. No virus was isolated.

Japanese summer or "B" encephalitis was the subject of a special instruction to the occupation force in Japan. This is outside the scope of this history, but a few features may be mentioned because the possibility of its occurrence in the Changi area on Singapore Island has been raised. In general it resembles the St. Louis type, and is believed to be transmitted by mosquitoes. Fever, clouding of cerebration, and various paralyses occur, and respiratory paralysis is common. Parkinsonian symptoms sometimes appear. Occasional encephalitic illnesses were reported from Changi in which the diagnosis of "B" encephalitis was suggested. The symptoms were in general similar: slight meningeal irritation was manifest, the usual headache and hebetude occurred, rigidity and tremor were sometimes noted, and also occasional epileptiform seizures. Most but not all the patients made a good recovery. The evidence is of course insufficient to allow an exact diagnosis to be made, but the suggestion is interesting.

NEURONITIS

From the early days in Palestine scattered cases of peripheral neuritis or neuronitis were seen among the A.I.F. Some of these showed affection of a number of neurons; others were strictly localised. Of the focal lesions facial, peroneal, radial and *serratus magnus* palsy were the most frequent. Some of these were no doubt due to trauma, but many were not. These lesions were observed both on home and oversea fronts throughout the war. Sometimes there was a clear history of injury, such as the familiar stretcher compression of the radial nerve. Sometimes injury seemed to be the probable cause though proof was lacking, as in some of the instances of involvement of the long thoracic nerve. *Serratus magnus* paralysis was

not uncommon, causing winged scapula, and in a few instances was bilateral. Carrying stretchers or ammunition seemed to bear a causal relation in some cases. Facial palsy often seemed to be in the same category as the other focal forms, but relapsing fever was always to be thought of in the Middle East, as mentioned above. Lieut-Colonel M. L. Powell reported from the 2/5th Australian General Hospital his observations of these lesions, and pointed out that fatigued men may more easily sleep in constrained and unusual positions, and that the loss of subcutaneous fat may increase vulnerability of certain nerves to injury. He mentioned specially the radial, ulnar, external popliteal, musculocutaneous and long thoracic nerves as vulnerable. The significance of this factor in debilitating illness has been mentioned in the section on typhus fever.

No doubt a presumed virus was sometimes blamed for a lesion due to pressure or other form of damage, but where trauma may reasonably be excluded, it seems justifiable to attribute the lesion to a toxic, or perhaps infective agent. Sensory involvement was sometimes found, but sometimes a pure motor palsy was the only finding.

In numbers of the focal types of palsy, a brief febrile disturbance prefaced the loss of power, and pain in the appropriate region was common also. For example, pain in the shoulder girdle often preceded paralysis of the *serratus magnus, spinati,* deltoid or *trapezius.* Increase in the protein content of the cerebro-spinal fluid was found in some of these focal palsies.

Some of these types of neuronitis resembled the Guillain-Barré variety, but conformity with the original description was much closer where the distribution of the lesions was anatomically wider. The "classic" type was seen in which after an initial febrile attack and a variable latent period, a sudden and widespread flaccid paralysis of muscles appeared. It is in this type that rapid deterioration and death may occur, apparently from cardiac failure. Dissociation of cellular and protein reactions of the cerebro-spinal fluid was sometimes found, but this finding appearing as it does in diverse conditions, is not *per se* of diagnostic value. As a rule, too, the affection was benign, though recovery was usually slow and sometimes interrupted by relapses, especially if strain was applied too early. Of course it does not follow that the nature of polyneuronitis is known because it may or may not conform to a pattern familiarised by one symptomatic description in the literature. Whether there are several infective agents concerned or not cannot be stated from the information available.

Polyneuritis sometimes seemed to bear some time-relation at least to other infections, but in countries where service carries a considerable risk of infective illness no conclusions can be drawn from this. For instance a member of the W.R.A.N.S. had a double foot and wrist drop following a *Salmonella* infection; this and similar observations may cause speculation, but the aetiology remains obscure.

Throughout the war peripheral palsies of all kinds were attributed by one or another to complications of known infectious disease. This was sometimes justified. Mumps, relapsing fever and typhus were good ex-

amples, but there was no warrant to incriminate a disease like malaria simply because it was frequent. A sequential relationship with, say, a diarrhoeal disease such as in the example above quoted is also insufficient for proof. Again, a familiar disease such as anterior poliomyelitis of known cause may simply explain all symptoms, without the need of invoking another cause. There still remain other varieties of polyneuritis or neuronitis of varying degrees of severity and distribution. Of these, apart from poliomyelitis, the most worrying were those which advanced rapidly from the periphery to involve the central nervous system. Respiratory failure might occur either from direct involvement of the muscles of respiration or from affection of bulbar centres. The latter, of course, had a very grave prognosis. The onset was not necessarily alarming. Motor weakness was first apparent in the lower limbs, with some loss of reflexes and perhaps some sensory symptoms. After a variable number of days rapid progression occurred and respiratory failure was threatened. Some of these patients died. Those with signs of bulbar palsy did not as a rule respond to treatment in a mechanical respirator. Others recovered even after a threat of circulatory and respiratory failure. For example, one man had pain in the limbs and double vision, soon followed by motor weakness in the face and all limbs, with slight loss of sensation. No abnormality was found in the cerebro-spinal fluid. Weakness in the external muscles of respiration followed, with palatal and laryngeal palsies, loss of deep reflexes and disturbance of the bladder reflexes. The diaphragm became partly paralysed, but despite this and the complication of pneumonia, the patient completely recovered.

In the section on diphtheria, mention has been made of the possible importance of diphtheria in causing polyneuritis. Instances can be quoted of apparently obscure attacks of polyneuritis which were found to be due to a previous attack of diphtheria, but the frequency of this can only be guessed. However, it is probable that diphtheria has really been overlooked in numbers of instances, although in Australian hospitals care was taken to investigate patients with neuritic signs to exclude this possibility. There has been a tendency too, in some quarters, to regard an increase of protein in the spinal fluid without increase of cells as a diagnostic feature of a neurological disease. It is important to realise that the Guillain-Barré syndrome is not necessarily due to one constant aetiological factor, and that certain of its features may be found in patients recovering from poliomyelitis and in the subjects of post-diphtheritic palsies. Experiences in the forces have shown that a throat swabbing may give a surprising result at times, and that a cutaneous lesion in a patient with neuritic signs should arouse suspicion, especially if sensory disturbances or deep pigmentation are found in its neighbourhood. With all these reservations, neuronitis may be regarded as forming a distinct category of nervous disease. Certain clinical neurological pictures were repeated on all fronts, despite differences in climate, location and endemic disease. When trauma, malnutrition, endemic infectious disease, diphtheria and known nervous diseases were excluded, there still remained a series of clinical states which

regularly produced and reproduced certain symptomatic pictures. In the present state of knowledge and recognising the possibility of multiple aetiology, these may be attributed with reasonable confidence to a toxic cause, possibly a neurotropic virus.

NERVOUS LESIONS DUE TO NUTRITIONAL STATES

The clearly-cut neural syndromes due to nutritional causes are described in the section dealing with malnutrition. The exact aetiological diagnosis could not always be made. When clinical syndromes of consistent type appeared in sequence with other evidence of malnutrition the relationship was reasonably clear. Encephalopathy, peripheral neuritis and spastic paraplegia appearing in a definite time-symptom pattern were clearly of nutritional origin. Sometimes the position was less clear. At Changi persistent foot drop lasting for months was classed as certainly due to neuritic beriberi, and lesser grades of weakness of the leg muscles with unsteady gait were included without hesitation. Men were seen, however, with ataxia and bilateral paresis of the muscles supplied by the circumflex nerve: they recovered, but the nature of the condition was uncertain. Beriberi could not be excluded, but was there in addition some other toxic or infective cause? This question cannot be answered at present.

OTHER NEUROLOGICAL PROBLEMS

One of the most difficult problems to settle was that of epileptoid or convulsive attacks. These were of two varieties, those believed to be due to epilepsy, and those occurring as an isolated incident, sometimes thought to be associated with intercurrent disease.

Epilepsy is incompatible with capacity for service with an armed force in time of war. A special question was inserted in the list to be answered by each enlisted man or woman. Even this often failed to elicit a history of epilepsy either due to suppression of facts, or lack of knowledge. The practical difficulty often arose of determining whether a given man had really had an epileptic attack, as such alleged attacks were not always seen by trained observers. Occasionally the patient's story was intrinsically convincing, as in an unusual case published by Noad in which a subject of uncinate fits gave a striking description of his symptoms. Narcolepsy was seen on a few occasions. The admission of four men with narcoplepsy into Concord Military Hospital in one quarter of 1945 is rather striking. It seems a remarkable coincidence for these to be sequels of previous encephalitic attacks, and one is reminded of recent well-authenticated instances of narcolepsy in which no association with organic disease was found.

A more difficult problem was that of men with unexplained convulsive attacks. Certain features were common to these incidents. They nearly all occurred in New Guinea or the neighbouring islands. They were unique, that is, consisted of a single episode only, and there seemed no evidence of their being truly epileptic. They were not always associated with endemic

tropical disease. Under the conditions prevailing in the more forward areas full investigation was difficult. Occasionally the death occurred unexpectedly of a man who had just had an unexplained convulsion, but even then autopsy did not always reveal the cause.

Cerebral malaria seemed the most likely organic cause, as these episodes occurred in men who had been exposed to malignant malaria. Post-mortem examination should have unfailingly revealed this cause had it been present, but it was not always possible for a skilled morbid anatomist to carry out the examination. Further, it was not always realised that brain smears made on slides as well as blood smears from cerebral vessels could be sent on for fuller examination. However, the clinical history of these men did not always fit into the picture of cerebral malaria.

It was, of course, possible that a convulsion might occur as an initial episode of a malarial attack. Against this must be set the observation that a number of these men were not proved to have a malarial attack, either on clinical or haematological grounds. Also, convulsions were very uncommon in severe malarial attacks, even among prisoners of war who were seriously malnourished, and who were often forced for lack of drugs, to make the best or worst of their attacks without alleviation. Scrub typhus was also suggested as a cause, since the onset was often rapid, and nervous complications were common. Here again, the after history of these men usually disproved this hypothesis. The possibility of some of these attacks being due to tetany merits fuller attention. Dehydration with significant depletion of body fluid and with hypochloraemia could easily occur in New Guinea and similar climates. Hyperventilation is possible, too, on exertion or in association with nervous causes. Alkalosis having been produced it is not difficult to precipitate tetany, particularly in susceptible subjects. The occurrence of epileptoid attacks in a state of hypocalcaemia has been recognised, and calcium imbalance may exist in an undernourished person or may be more easily produced.

J. E. G. Pearson recently described epileptic attacks in an officer of the R.A.F. due to tetany. Malaise, anorexia and vomiting associated with prepyloric ulcer induced dehydration, and later biochemical investigation showed that the fits were due to acute tetany. The tetanic threshold is more easily passed in some persons than in others: the same applies to convulsive attacks. No further evidence can be offered, but the suggestion is worth remembering.

A further suggestion has been made that an adverse calcium balance might arise from the use of wholemeal bread. The addition of a calcium salt to wholemeal has been practised to counteract this, and tetany has even been attributed to phytic acid poisoning. Stanton Hicks has, however, pointed out that within the last century wholemeal was consumed by all races in Europe, apparently without their suffering from any obvious ill effects of adverse calcium balance. In any case, Australian troops in New Guinea never received the equivalent of wholemeal. They may have received wheat germ, but not phytic acid, which is in the bran. Therefore, this nutritional factor as a possible precipitant of some of the evil effects

of diminished intake of calcium, is of no importance in this particular problem.

It may be remarked in conclusion that tetany as a medical emergency may easily be overlooked.

In addition to biochemical causes, the possibility of malnutrition must also be considered. This would seem unlikely except under conditions of dietetic insufficiency of severe grade, such as prevailed in some Japanese prison camps, where deficiency states like Wernicke's encephalopathy were observed. Though epileptoid seizures were rare, it is of interest that they appeared in sequences in some areas, but the explanation is obscure.

The problem of diagnosis of pains of sciatic type and distribution arose not infrequently, and at base hospitals lesions of the intervertebral discs were recognised and treated. Treatment was usually carried out by surgeons interested in neurosurgical or orthopaedic work; it is dealt with in the section on orthopaedics.

PERSISTENT HEADACHE

Headache was a frequent complaint at sick parades and in patients coming before medical boards. The occurrence of headache after meningitis has been mentioned. Many men who complained of headaches in the early stages of the war gave a history of previous head injury and due care was taken not to enlist men with such a history. Some men complained that the glare of strong light caused headache—the same symptom is met after head injury. Others complained that drill or exertion had the same effect. Large numbers of refraction tests were made in all the Services, and a considerable number of corrective glasses ordered, but the effect on the headache was not striking. There is little doubt that in men who gave no relevant history or presented no evident stigma of disease or injury, the headache was chiefly, if not entirely psychoneurotic in origin. Sometimes it was possible to discover a factor in the soldier's background or domestic life. More often reassurance and return to work was the best treatment, at least it often eliminated the unfit.

The complaint of headache was often linked with "black-out". This was for a time one of the most popular complaints made at sick parades. Few men knew what was really meant by the term; the commonest meaning assigned was temporary faintness or giddiness. It was seldom that any special action was necessary for this vague symptom. Even when based on a distinct degree of discomfort, which was often doubtful, it assumed a much more prominent position in the field of consciousness than its importance warranted.

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CHAPTER 27

DISEASES OF THE URINARY TRACT

NON-SUPPURATIVE affections of the urinary tract were not common features of service medicine. The ureters and bladder were more commonly affected than the kidneys.

RENAL DISEASE

Nephritis was rare, and no particular association with streptococcal infection can therefore be recorded. Though nephritis is known to be a complication of quartan malaria, it did not occur in this connection, for quartan malaria was itself rare, as might be expected by its known natural history. The suggestion was at one time made that there might be a renal factor in the production of oedema in prisoners of the Japanese who suffered severely from malaria. No convincing evidence was brought forward to dispute the importance of lack of protein in the diet as the chief cause. Acute glomerulo-nephritis was reported as occurring in a few fatal infections of acute dysentery of the Shiga type, among British troops in Egypt. No instance was recorded among Australian troops. It seems possible that dehydration may have been at least a contributory factor here. During 1942 in the El Alamein area, a number of men were seen with what appeared to be a nephrotic syndrome, with oedema and proteinuria, but no casts in the urine. The A.D.M.S. of the 9th Division warned medical officers to be cautious in making a diagnosis of nephritis in the absence of casts or cells in the urine. Dietary deficiencies were considered as a possible cause, but no evidence of this or any other causal factor was found. Nocturnal diuresis was reported by H. A. Phillips and others to be common among undernourished prisoners of war on inadequate diets, but there was no suggestion that there was any essential or intrinsic renal cause.

The well-known renal complications of the less soluble sulphonamides were occasionally seen. Crystalluria was not uncommon in patients being treated with sulphonamides, but was not always associated with symptoms. No trouble was experienced with sulphaguanidine in this respect, though crystals were sometimes found in the urine as the soft nature of the crystals of this drug prevented irritation or blockage of the ureters. With sulphapyridine and other compounds of this series occasional blocks occurred, sometimes in spite of an apparently free and sufficient administration of fluids. It was at first thought that sulphamerazine, by reason of its rapid absorption and more leisurely excretion would not cause blocking in the renal tract, but cases were reported at intervals. Anuria occurred occasionally with this drug also, in spite of the theoretically minimal risk. No definite evidence was found of toxic effects on the nephron, that is, the glomerulo-tubular unit of the kidney. This toxic effect must surely be rare, when we consider the conditions under which the sulphonamides

were administered, with great strain on the fluid balance mechanism of the body from loss of blood or tissue fluids.

In the Middle East, as in other hot countries, renal colic and signs and symptoms suggestive of calculus formation were relatively common, especially during the hot weather. Numbers of medical units in widely scattered areas reported these conditions. In Palestine and later in Syria, oxaluria was common, usually among patients complaining of some urinary irritation. Red blood cells were sometimes found in the urine on microscopic examination. Occasionally radio-opaque calculi were demonstrated by X-ray examination. In at least one instance early investigation of a soldier complaining of symptoms of ureteric irritation revealed no radiological abnormality, but a year later there was a demonstrable stone in the kidney. In the majority of these subjects of urinary irritation no calculus could be found. The cause of the oxaluria was not determined: it was thought to be due to some extraneous source in food or water, though no proof was adduced. Relative dehydration from excessive sweating and sub-optimal intake of water must also have been an important factor by producing concentration of the urine. A similar condition was also found among servicemen in various parts of Australia. In Adelaide in 1943, a number of patients were treated in the 101st General Hospital for renal colic. All of them had red blood cells and oxalate crystals in the urine. In the Northern Territory also oxaluria was found to be common, with concomitant symptoms of irritation. In 1945 in Balikpapan, the 2/12th Australian General Hospital reported a high incidence of renal or ureteral colic. In some instances small stones were found by X-ray examination.

PYOGENIC DISEASES

In 1940-1941 in Palestine numbers of cases of pyuria attracted attention. Frequently no organisms could be found; in some, however, bacteria of various types were abundant. Cystitis was present as a rule, also purulent inflammation of the adnexa, and it was customary at some stage to find a coexistent urethritis. As a rule, but not invariably, there was a history of possible exposure to venereal infection. It was at this time that numbers of the so-called "non-specific" forms of urethritis attracted attention. This subject is dealt with in the section on venereal disease. Leaving on one side as more easily explained the bacterial forms of pyuria, the abacterial forms have to be accounted for, and it is difficult to dissociate them from "non-specific urethritis". This condition, whatever its aetiology, was often a clinically associated feature of "abacterial pyuria". The onset of this pyuric disease was sometimes suggestive of a general infection, with malaise and slight pyrexia. Urethritis sometimes appeared at a later stage, or at least became obvious then, and the history and development of the condition at times suggested that its origin was not always venereal. Close reported from Adelaide the occurrence of a mild chronic vesiculitis of non-specific cause, difficult to recognise and slow to resolve. It was not in any way related to venereal disease, and not a complication of such. Similar conditions were seen in other areas from time to time.

At Nakom Paton, in Thailand, Fisher reported pyelitis as being common during the last year (1944-1945). Slight malaise and pyrexia ushered in the illness, pus appeared in the urine, and sulphonamides appeared to be effective. But he also recorded that a non-specific epididymo-orchitis was not uncommon: in a few men this went on to suppuration and orchidectomy was necessary. Phillips observed a large number of cases of non-specific inflammation of the urinary tract, possibly related to malnutrition.

Though the evidence presented here is of necessity somewhat vague, it is derived from many fronts over a period of a number of years, and points to the existence of a clinical entity. This "abacterial pyuria" appears to be a disorder of a distinct kind, a view supported by the belief of venereologists that there are "non-specific" forms of urethritis not demonstrably due to, or complications of, gonococcal infection. Some observers have found spirochaetes in the pus in this condition, and have sometimes reported good results from the use of arsphenamine. Arsenic has proved disappointing in the hands of Australian observers, and no evidence of a spirochaetal origin can be offered here. In view of the finding of pleuropneumonia-like bodies in non-specific urethritis it may be admissible to postulate some relation between this organism and the lesions of abacterial pyuria. Treatment of these states was unsatisfactory and prolonged. Sulphonamides appeared to be entirely without effect, and they responded only slowly to local irrigation with mild antiseptics. This brings us to consider the controversial syndrome first described by H. Reiter in 1916.

REITER'S SYNDROME

Little attention was paid to this condition during the war in the Australian Services, and no collected studies were made. Yet records show that cases were seen, and the chief features recognised.

It is of historical interest that Reiter's first patient had blood-stained diarrhoea, which is a common initial symptom, though the syndrome is now recognised by a diagnostic triad of non-specific urethritis, conjunctivitis and arthritis. Investigation has shown that the diarrhoea was not due to bacillary dysentery. It is of course known that arthritis and conjunctivitis occur as sequels of dysentery, particularly of the Shiga type. Among Australian troops in the Middle East such sequels were more frequently seen before the introduction of sulphaguanidine. Both monarticular and polyarticular forms of arthritis were seen after dysentery, but it is interesting to recall that in several patients with the monarticular forms generally regarded as a characteristic sequel of bacillary dysentery, investigation showed that an active dysenteric lesion was still present. Though polyarticular types were also seen, they were similar in nature to others occurring in patients who had never had diarrhoea. A few patients in Palestine with arthritis affecting several joints after Shiga dysentery did not respond to the administration of concentrated Shiga antitoxin. They also had either conjunctivitis or iritis, and in one instance urethral discharge was observed, from which no organisms could be cultivated. In other patients who had never had dysentery, polyarthritis was observed

with no evidence of gonorrhoeal infection. In one such patient a hyperkeratotic condition of the skin was seen and described as *Keratodermia blennorrhagica.*

There seems, therefore, no warrant for considering Reiter's syndrome as aetiologically related to either dysentery or gonorrhoea. The point has been made too, that it is not more frequently seen in countries where dysentery is endemic. It has been suggested that the syndrome is an allergic manifestation arising out of several different conditions. A mild fever is usually described as the initial symptom, with or without diarrhoea, and a number of days afterwards a profuse mucopurulent urethritis and conjunctivitis appear, after which the weight bearing joints become inflamed and tender. The arthritis is often of resistant type. Pleuropneumonia-like organisms have been found in the discharges, which suggests some possible connection with non-specific urethritis, or with abacterial pyuria.

During the war years epidemics of diarrhoea occurred in various parts of the world believed to be of viral origin. Epidemic kerato-conjunctivitis also due to a virus was recognised in several countries during the same period. These facts are merely mentioned in a speculative way; there is no suggestion that they are related. The aetiology of Reiter's syndrome still appears to be obscure, but in view of the occurrence of urinary symptoms, and the obscure nature of the abacterial forms of pyuria, the syndrome is here included, perhaps illogically, in this section.

Treatment was unsatisfactory and progress slow as has only too often been so with polyarthritis. Severe lasting disability has occurred in a few men following an attack of proven bacillary dysentery of Shiga type, possibly as a complication of the disease. It would seem that at least with the methods available up to the end of the war, whatever the aetiology, multiple arthritis produced changes difficult to reverse.

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SECTION 3 — DISTURBANCES DUE TO NUTRITIONAL AND PHYSICAL CAUSES

CHAPTER 28

MALNUTRITION

IN the armed forces of a nation at war, it is necessary to keep constant watch for any signs of nutritional disturbances. Defective nutrition is not always easily diagnosed in its earliest stages, especially when due to vitamin deficiencies. Recognition of the so-called subclinical types is mainly speculative. It is obvious that many causes may be responsible for deterioration, of which food is only one, and even when demonstrable signs of disease appear it may be impossible to distinguish which are due to lack of specific balanced factors in the diet. Further, however ideal a dietary may be on paper, it may not always be translated into terms of food presented to the soldier, owing to difficulties of transport or of military conditions. Food may not be presented in a palatable or assimilable form, and its final absorption may be hindered by disease.

The story of rations in relation to the demands of nutrition is told elsewhere. Here we are concerned with the results of defective nutrition in the armed forces.

Both in Australia and in the Middle East, in 1940, the possibility of the occurrence of nutritional deficiency was raised, in spite of the adequate dietary scale.

1. NUTRITIONAL DISTURBANCES IN THE MIDDLE EAST

In Palestine during the summer of 1940, the prevalence of shallow indolent ulcers on the exposed skin surfaces raised the question of a possible deficiency of vitamin *C* in the diet. This has been dealt with in the section on dermatology. No evidence supporting such a dietary lack was brought forward at the time, but the limited observations made on this specific point, either during the 1914-1918 or the 1939-1945 war, may not yet be conclusive. "Pure" deficiencies of a single chemical constituent of a dietary are not in any case often met in clinical practice.

Apart from the occurrence of skin ulcers, some evidences of slight lowering of nutritional standards were occasionally seen in Palestine, though these were not significant. Even in the base areas some loss of weight was observed, and occasional reduction in haemoglobin, especially in members of the nursing service. Incidentally, the need for calibrating standards of haemoglobinometers was found in the Middle East, and all readings could not be taken at face value without correction.

During 1941, the lack of green vegetables was felt by the A.I.F. in some places in the Middle East. Even in base areas such shortages were felt,

even though no obvious bad results followed. In some forward medical units ascorbic acid tablets were added to the rations to make up for this lack. In Tobruk the diet was satisfactory for the greater part of the siege, despite the slender supply line, but some gaps occurred. Supplies of ascorbic acid were not consistently maintained, and the ideal advice of the hygienists concerning supplements could not be followed because of lack of certain supplies, including synthetic vitamins, in the Middle East war zone. The deterioration through time of "Marmite" as a source of the vitamin *B* complex was taken into account in its therapeutic use. Australian margarine was not in all ways satisfactory in this ration, some of it contained 10 per cent butter, but it was not reinforced with vitamins *A* and *D*, as was the English product, which was preferable. Owing to technical problems, butter could not then be transported in tins from Australia or kept under conditions of great heat without deterioration. These problems were encountered in Australia also, when, after the completion of a new road linking Adelaide with Darwin, supplies were sent to the Northern Territory by road.

Examination of Italian biscuits after the retreat of the Italian forces showed that these were a better source of thiamin than the Australian biscuits, which contained 1.93 microgrammes as against 2.5 microgrammes in the Italian product. The last mentioned was believed to be made from a superior wheat flour used for spaghetti. The Australian biscuit was not a popular success; though different manufacturers turned out from the same formulae products differing widely in taste and texture, the strain on the teeth and the unexciting flavour did not please the soldiers.

2. *NUTRITIONAL INVESTIGATION IN AUSTRALIA*

Meanwhile in Australia, attention was drawn by the Nutrition Committee of the Commonwealth National Health and Medical Research Council to vitamin deficiencies in Australian diets. The committee pointed out that whole meal was desirable, that more fruit and vegetables should be available, and the value of cooking potatoes in skins should be recognised. So hard is it to overcome prejudice and custom that it was still possible late in the war years to witness the unnecessary labour of peeling potatoes, even in service medical units. Current medical literature pointed out the importance of known aspects of deficiency diseases, such as those due to lack of riboflavin, and valuable research was carried out on the vitamin *B*1 content of Australian white bread. *B*1 was shown to be the only element of the *B* complex present to any extent in white bread. Methods of reinforcement were suggested, but objections of technical nature and of public taste were expected. It is curious how widely has spread a taste for white flour, one of the doubtful gifts of civilisation.

During the recruiting and early training in Australia of the 8th Division certain dietary deficiencies were suspected, and a small test series was investigated by the 2/9th Australian Field Ambulance. Using volunteers, a three day test of saturation with vitamin *C* was made. Though no clinical deficiency was demonstrated, a number of private soldiers, but not

officers, were found to have deficient saturation. The diet supplied at the time in camp contained too much bread, potatoes and flour, and not enough fruit, milk and greens. Normal leave period allowed most of the men to supplement the camp diet. This experiment was on a small scale, but in December 1940, the Director-General of Health informed the D.G.M.S. that the nutrition committee recommended that the vitamin *C* saturation of soldiers should be investigated in each command. The technique adopted was to test the urine for ascorbic acid, then to administer 300 milligrammes of ascorbic acid, and repeat the test four hours later. The results showed that saturation was by no means constant. In the Northern Command, for example, only one-third of the troops were in a condition of vitamin *C* saturation. Later in the Northern Territory the D.D.M.S. of that area warned of the possibility of a vitamin *C* deficiency there. A suggestion was also made of a connection between vitamin *C* deficiency and gingivitis, but no convincing evidence was produced. Vitamin deficiencies were seen sometimes in natives in the northern parts of Queensland and other more isolated parts of Australia, but the troops in these parts in practically every case had no trouble.

The Council for Scientific and Industrial Research (Division of Food Preservation and Transport) carried out experimental work on the supply of vitamin *C* for defence purposes. Lists were compiled for Australian use, setting out the concentration of ascorbic acid in local foodstuffs. Difficulties were encountered in producing fruit juices without loss of the vitamin content, by reason of intrinsic drawbacks to such processes as spray drying, want of correctly lacquered tinplate containers, and loss of flavour.

This interest in vitamin *C* was of value, as it laid emphasis again on the need for fresh fruit and vegetables, though it was not easy to translate this into terms of achievement. This difficulty was sometimes a real one in revictualling ships of the Royal Australian Navy, especially in some ports, where sufficient supplies of fresh food could not be obtained. In December 1941, for example, H.M.A.S. *Westralia* was unable to get good meat or fresh or tinned fruit in any quantity in Darwin. Investigation showed that twenty-four out of twenty-nine ratings had a deficient reserve of vitamin *C*. As will be told presently, gardens alleviated such shortages to some extent, though in great areas like Northern Territory the transport difficulty was considerable. At a later period, in June 1943, naval ratings admitted to the naval hospital at Darwin were found to present some signs of avitaminosis. Though efforts were constantly made to supply fresh vegetables, fruit and milk to ships' companies, criticisms were levelled at the slight margin of vitamin *C* available. The daily issue of lime juice was sometimes the only source, but tomato juice was also supplied. Issue lime juice had little antiscorbutic value, and it was suggested by one medical officer that a drink might be made from dehydrated lemon juice, corn syrup and ascorbic acid. When the diet as presented to the army and air force sometimes consisted chiefly of meat and potatoes, with only a small amount of powdered milk and cheese, there must also have been

temporary shortage of calcium and vitamin *B*. At the Darwin naval station, within a year some six cases were seen in ratings of oral lesions believed to be due to riboflavin deficiency. Several medical officers considered that certain symptoms were due to "subclinical" avitaminosis, such as headache, anorexia, dizziness and slight muscular tremors. No accurate studies were made, but response to a more balanced diet was observed, and it is possible that there was a nutritional basis.

One instance of inaccurate statement should be mentioned, as an indication of what harm this may do. A report emanated from an investigator in Adelaide who was working on methods of packing cabbage in tin plate so as to preserve its content of vitamin *C*. This reached Washington in the form of a rumour that a serious outbreak of scurvy had occurred both in the Northern Territory of Australia and the islands, affecting a large proportion of men. This was completely untrue, as only two instances of malnutrition owing to lack of ascorbic acid had been found in the Australian armed forces at that period. Other exaggerated statements were made from time to time, and some were published, but their basis was always very slender, and usually non-existent.

The abnormal factors in the local food problems of the Northern Territory and New Guinea were recognised, particularly with regard to fresh foods. Where civilians could not be employed in certain areas because of their declaration as operational zones, and therefore supply by contract was impossible, the joint needs of the Australian forces and later the British and American forces in the South-West Pacific Area, together with those of civilians, exceeded Australia's productive capacity for fresh foodstuffs. Therefore coordination of requirements was effected under the Department of Commerce and Agriculture, and in the special areas mentioned, farm companies were organised under the Australian Army Service Corps. These were most successful projects, and provided fresh foods for the Services, saved transport and refrigeration space, and reduced cost as well. In the various internment camps in Australia, also, extensive gardens were maintained by the use of voluntary labour of prisoners, and the production of supplies greatly in excess of local needs, other sources being thereby supplemented. These measures lessened the monotony of tinned and dehydrated food, and the coincident efforts of the Catering Corps to improve the preparation and economical handling of food, helped to feed the men doing the jobs of war. The development of farm units in Northern Territory, Central Australia, Queensland, Cape York Peninsula, New Guinea, New Britain and Solomon Islands under control of the Directorate of Supply and Transport undoubtedly had a far-reaching effect on the health of troops.

Refrigeration was an important matter too, particularly with the expansion of service requirements for the defence of Australia. Late in 1939 the Military Board recommended that power refrigerators should be installed at camps throughout Australia. Though business advisers were at first opposed to this, and suggested the use of drip safes and ice chests, expert opinion stressed the much greater efficiency of powered units. Stan-

dard units of robust construction were eventually supplied, simple to maintain and to move. Though at first the army relied on Red Cross gifts of refrigerators to keep essential medical supplies such as antisera at the proper temperature, refrigeration won its recognition as an essential requirement wherever it could be installed, especially in tropical areas.

One matter related to environmental conditions in the tropics is the salt and water requirements of the soldier. This was seriously considered in the Middle East, and reinforcement of drinking water under working conditions of intense heat was sometimes used. This is referred to also in the section dealing with environment. Salt tablets were provided in the islands, containing crystalline table salt with a prescribed content of calcium and magnesium salts.

A practical trial of methods in the field was made in 1942 under the supervision of Lieut-Colonel Sir Stanton Hicks, Chief Inspector of Army Catering. He had pointed out that fresh food supplements were necessary in the Northern Territory, and that special convoys were needed to maintain the protective value of food. In the north-western part of Australia in 1942-1943 a special independent group and a guerilla warfare group were used to study problems of feeding. At one time these troops had eaten from tins, with no fresh supplements; their health was not good, and sores on the skin were common. When wheat and blue peas were made available, using the germination method as used by Captain Cook, together with yeast, bread of 60 per cent whole meal and tablets of lucerne and ascorbic acid, the troubles all vanished. These men were able to maintain health and vigour and to be independent under exacting conditions.

On the whole, servicemen in Australia maintained a satisfactory grade of nutrition. An occasional instance of mild deficiency was seen, of the type not uncommon in civil practice, caused by a combination of unwise selection of food and infective illness. In the Base Military Hospital in Perth, Western Australia, six mild cases of deficiency were reported in some four months, two being in civilians; two patients showed glossitis and cheilitis, and the others corneal vascularisation, anorexia, some oedema, and lessened response to effort.

Men returning from New Guinea or Timor in 1943, who had lived under extremely trying conditions, sometimes being forced to subsist on the country unaided, often showed signs of malnutrition, and vitamin supplements were needed in their treatment, when admitted to hospitals in Queensland. In the Northern Territory a few patients with mild *B*1 vitamin deficiency were seen. One interesting feature there was that on the few occasions when symptoms of deficiency appeared, they were of the nature of a neuropathy, and lesions of the tongue and mouth were infrequent. It will be seen presently that in 1943 the opposite was found in New Guinea.

In 1943, a medical officer was appointed to the staff of the Medical Directorate to act as liaison officer to "Q" branch (Nutrition) of the army. Surveys of local conditions in all areas were made, and studies carried out on the food pattern preferred by the Australians on service.

Information was obtained as to the acceptibility of various foods. "Bully" beef was still a favoured and staple source of protein, but where air transport was possible, frozen boned beef met with great success. Dehydrated mutton was not successful and was given up. Dehydrated eggs required an enlightened cook, and survived their first bad reputation when methods of production improved. Dehydrated vegetables varied in acceptability. "Goldfish", the unpopular tinned herrings and pilchards, were disliked in New Guinea as much as in the Middle East. They were simply unacceptable to most servicemen, although civilians deprived of tinned fish welcomed an occasional tin as a change from their own often dull ration. It may be noted in passing that civilians in the northern States in 1942-1945 were worse off for varied food rations than in the southern States, owing to the demands of the forces in the north and the better manufacturing and distributing facilities in the south.

The value of all the effort and research expended on the subject of food, in all its aspects, was of course not only in its reflection on the well-being of the fighting soldier and all those behind him, but also in its prophylactic importance. Without this care malnutrition might have been a great danger, especially to troops or civilians exposed to fatigue and hardship. The importance of these factors will be stressed as this account proceeds. Many examples might be quoted. For instance, after the Italian defeat, some of the Italian prisoners of war in Egypt showed signs of pellagra. The effect of the hard days of defeat with poor and insufficient rations was later evidenced in men captured by the Germans in Greece. The latter were not so fortunate as the Italian prisoners, whose symptoms were quickly relieved by yeast.

3. NUTRITIONAL DEFICIENCIES IN THE PACIFIC ISLANDS

In island warfare conditions of feeding were made more difficult because of uncertainties of transport by arduous and complicated routes; particularly trying were the last laps of these journeys to landing points and thence to forward units. Dropping from the air was used considerably in New Guinea, and in spite of an unavoidable wastage rate, it was a successful, and sometimes the only practicable, method.

An intrinsic weakness in the distribution of rations was that the innate selfishness of man intrudes: the temptation to abstract the more popular and varied items and to pass the remainder to those beyond was not always resisted, despite the greater needs of the forward troops. The introduction of the individual forward operational ration overcame this. This ration was palatable, easily consumed and self-contained. Perhaps it met too completely the desire for sweet food so common among Australians serving in the varied climates of New Guinea, and the men tired of it, but it had many advantages. Scientifically perhaps, the accuracy of some of the descriptive labels on parts of these packs could be questioned. Perhaps for propaganda it is justifiable to inform the soldier that a food

contains vitamin *A* which "increases resistance to common diseases" even though the truth of the statement may be questioned.

In December 1942 it became evident that the force in Milne Bay which had been irregularly served by sea transport was receiving a very unsatisfactory diet of low vitamin content. No refrigeration was then available. The men were heavily infected with malignant malaria. The medical services pointed out that there was grave risk of deficiency disease on a wide scale unless adequate quantities of protective foods were sent straightaway. Medical comforts for hospitals, containing additional sources of vitamins were listed, and action was taken to improve conditions. The Deputy Assistant Director of Hygiene of New Guinea expressed the opinion in 1943, that poor diet was a contributory factor to the high incidence of malaria. Many were receiving a diet notably deficient in vitamin *B* complex. The chief dietary need at the time was an adequate ration actually reaching the men, and where this was not possible an issue of vitamin capsules for front line fighters was suggested. Brigadier Disher, D.D.M.S., New Guinea Force, noted too that the nearer the front line the poorer were the rations; here bully beef and biscuits were too often the staples. The ratio of sick to wounded of the 7th Division in hospital was 7 to 1 with active fighting going on between Kokoda and Buna. The men returning from the Kokoda trail were not only fatigued and worn out by the hard conditions and disease, but by subnutrition as well.

At this time, too, the danger of beriberi in native carriers was recognised, and occasional instances were seen. Precautions were taken to ensure adequate diets for these men, at the instance of the medical advisers in New Guinea, and stress laid on the risks of polished rice. There were then only 60 pounds of "Marmite" on the island, and no substitutes were to hand. This was needed particularly for these native carriers, and was dropped from the air to forward posts.

When the stress of the first New Guinea campaign was over and supplies could be more easily obtained, the general standard of health improved. This could be seen in the troops, whether resting, in active work or in hospital, even though more of them had declared evidence of specific deficiency states. During 1943, the less rushed nature of work in the medical units in New Guinea gave opportunity to more detailed study of the problems of nutrition. The vitamin *B* complex in relation to clinical syndromes owing to lack of some of its components aroused special interest.

The position with regard to *B*1 deficiency could easily have been confused, possibly it was at times, for polyneuronitis in localised forms was not uncommon in men whose nutrition was quite satisfactory. It is of course possible that neurons might withstand the assault of a neurotropic virus less well if protective substances were lacking in the diet and therefore in the tissues. There was no doubt that occasional instances of *B*1 deficiency of the neuritic type were seen as well as polyneuritis. The combination of oedema, even if slight, muscular weakness and sensory disturbances, was sufficiently definite for diagnosis. However, a diagnosis of *B*1 deficiency was made without warrant on occasion, on the slender and

inconclusive evidence of subjective sensory changes. A technical instruction was issued in the army directing the attention of medical officers to the findings of physicians in a semi-forward area; this described a syndrome of deterioration of health and stamina, combined with analgesia to pin prick on the extremities. As might be expected, sensory changes became rather a popular symptom and after critical review of a test series with controls, the instruction was withdrawn and replaced by another laying down more rigid standards. These included decreased or absent tendon reflexes, weakness of muscles, as shown by failure to perform the squatting test, pareses or paralyses. Foot drop and hand drop if present formed part of a progressive picture. General signs of malnutrition were to some extent confirmatory, so too was oedema of the legs. Sensory changes were reliable only if established beyond doubt, and included paraesthesiae, hyperaesthesia or proven sensory loss. There is no doubt that some of the sensory phenomena in earlier groups of men were largely of hysterical origin.

Further examples of this will be given later. No serious syndromes, such as cardiac beriberi, appeared.

In general, though malnutrition was seen during the early strenuous periods in New Guinea, clear cut pictures of specific avitaminosis were very uncommon.

At a hospital in Moresby, only a small number of undoubted instances were seen, and these were mild in nature, the men seldom showing more than pre-tibial oedema, diminished tendon reflexes, anorexia and debility. As an empirical measure thiamin tablets were given for 7 to 10 days to all men who had been long exposed to bad jungle conditions. Such men had usually been in patrols away from main bodies of troops. The medical advisers of New Guinea Force stated late in 1942 that patrols, commandos and watchers needed supplementary rations.

In 1943, the catering corps early began to demonstrate methods of attaining a sufficient supply of vitamins, especially the *B* complex. Measures specially advised were the fortification of bread and the use of dehydrated butter and germinated blue peas. Perhaps on the clinical side too much emphasis was laid on the importance of the *B*1 part of the *B* complex. On the one hand the soldiers' dietary must give him confidence; on the other hand watch must be kept for the appearance of the earliest signs of deficiency after a latent period, and the signs usually attributed to lack of thiamin are manifest soon after a term of poor diet. Early in 1943, however, signs of another kind were recognised. At the 2/5th Australian General Hospital men were seen with lesions of the mouth and tongue in addition to mild neuritic affections.

Treatment with thiamin, nicotinic acid and "Marmite" in addition to full diet, soon relieved all these conditions, and in 6 to 8 weeks dulled or absent deep reflexes were active and full muscular power had returned. A search through the wards revealed an unsuspected group of ten men with fissuring of the angles of the mouth, and in some, denudation of the tongue with painful margins. They recovered promptly on treatment. Com-

parison of the diets of these men while in forward areas with the diets of a control series showed the following shortages. Calories consumed averaged 2,800 per day, the full requirement being 4,500; protein, fat and carbohydrate were adequate and proportionate, but vitamin *C* was deficient (4 milligrammes or less a day of ascorbic acid), and vitamin *B* complex was assessed at 160 to 400 I.U. a day, though the metabolic requirements in a tropical zone were at least 800 I.U. per day.

It is fair to state that defects in the rations of men in operational areas were owing to a failure of full supplies to reach them, not because of an intrinsically defective dietary scale, but through extreme difficulties of transport. Changes in the military situation and improvements in the food supplied promptly removed the risk of further deficiencies of vitamin *B*2 revealed in this small series. Lieut-Colonel Dods pointed out that patients of this type would recover readily while at rest in hospital without further treatment, as the patients' dietary in the 2/5th A.G.H. in the Moresby area was at that time estimated to contain 3,000-4,000 Calories, protein 1 to 2 gramme per kilogramme body weight, vitamin *A* 10,000 to 30,000 units, vitamin *B* 700-1,000 units and vitamin *C* 100 to 200 milligrammes daily.

Major Rose, in a report on vitamin deficiencies in New Guinea, covered the period from Christmas 1941 to March 1944. In the early part of this period all troops were in the Moresby base area, and no sign of food deficiency was seen. During 1942, 180 men and a few women and children were rescued from the Jacquinot Bay area some three months after the fall of Rabaul. Almost all of these survivors had malaria and diarrhoea. They had fed on vegetables only, with the rare addition of a very little meat. Many of them had general oedema, but even so they had on the average lost some two stone weight. The oedema was, of course, famine oedema, though estimations of protein in the blood could not then be made; the response to thiamin, even in large parenteral doses, was negligible. Most of these people also had sore and atrophic tongues.

Similarly affected were men in one group who returned after the Kokoda action. A number of men of the 2/27th Battalion, cut off in the bush behind Nauro, had oedema which subsided in some six weeks. Some of these had diarrhoea which would not yield to standard measures, including sulphaguanidine. Their tongues were atrophic and occasionally sore, and on a regime of nicotinic acid and "Marmite" they rapidly recovered. They undoubtedly had some symptom of pellagra. Another group of men from the 2/14th, 2/16th and 39th Battalions had neuritic symptoms. The deep reflexes in the legs were either exaggerated or almost absent, and they suffered from burning pain in the feet. On full diet with extra thiamin they recovered only slowly, but the addition of "Marmite" quickly relieved them. This group appearance of deficiencies of various components of the *B* complex is to be specially noted, for it was found to be a feature of the unhappy experiences of the 8th Division in captivity.

From "Kanga Force" in the Wau area a large number of men were sent to hospital with a diagnosis of beriberi. Analgesia was common; it

was noted over a wide area of body surface, but with no relation to the established pattern. Sluggish reflexes were frequent; so too was slight oedema of the ankles. These men had recurrent malaria and had been on a low diet for some time; but the diagnosis was questioned in hospital, especially as the more reliable sign of tenderness of the calf muscles was absent. This opinion was confirmed by the arrival of men of the 17th Brigade who, though in the area only six weeks, complained of the same insensibility to pain. Some genuine, though mild examples of deficiency states, were seen from the Wau sector, where hardship had been suffered, but the symptoms were much exaggerated, and in some men they were feigned; the existence of mass hysteria was further confirmed by magic cures wrought by injections of sterile saline, or merely by unaided suggestion. By contrast, one of the curiosities of this period was a man who had worked for over a year in a bakehouse in Moresby town area, and who had genuine neuritic beriberi.

About the same time, an increased number of men from the Moresby base area were found while under the treatment for malaria or other infection, to have angular stomatitis, cheilosis and glossitis. Symptoms were relieved by "Marmite" taken for 5 to 6 days, though recurrences were frequent. A suggestion made at the time was that a chemical incompatibility existed between riboflavin and atebrin, which was then being taken in suppressive doses. No evidence of this was found in other campaigns. Later, the men coming through Lae from the Ramu Valley and Finschhafen campaigns not infrequently showed these lesions, though other signs of deficiency were absent.

No scurvy was seen, nor any sign of the toad-skin manifestation of vitamin *A* deficiency. There were, however, occasional instances of scrotal dermatitis among men with other evidences of lack of riboflavin, but the full significance of this was not realised at the time.

The later years of the island campaigns added no new experiences in deficiency diseases. In 1944 and 1945, occasional examples of thiamin deficiency were seen, for instance among the Chinese at Madang and Yalu who had been in Japanese hands, and who improved rapidly on thiamin. In general thiamin deficiency was not at all common in the islands; mild manifestations of *B* complex deficiency were more frequently seen. Single deficiencies were rare, and malnutrition, combined with fatigue, appeared in many variants, depending to some extent on the different metabolic characteristics of individuals. In the island campaigns correct rationing, efficient delivery and preparation of food and careful medical supervision prevented malnutrition from being a serious waster of men.

4. NUTRITIONAL DISTURBANCES IN PRISON CAMPS IN EUROPE

Experience has shown that prisoners of war may arrive in prison camps in a state of poor nutrition if they have passed through previous stages of siege, retreat and disorganisation followed by exhausting journeys with

poor and insufficient rations. To this, add the effects of the anorexia of mental depression and the likelihood of confused organisation of and in the camps, with the difficulties of commissariat, transport and language, and disorders of nutrition may easily be produced. Where the prisoners' rations were ill-balanced and meagre, as too often they were in the experience of our own captured troops, the risk of deficiency disease was considerable. In certain prisoner-of-war camps in Italy and Germany well-defined deficiency states were recognised.

(a) *IN ITALY*

In Gruppignano, No. 57 in Italy, during the first part of 1943, bad conditions were encountered. Lack of sufficient or proper food was responsible for beriberi and other deficiency states mainly among men captured in Egypt and Libya during 1942. The concentration camp there was not properly organised and many men arrived at the European camp exhausted. The diet consisted of small quantities of stew or macaroni soup, with very little meat, and 100 grammes of bread. Some help was obtained from Red Cross parcels and a little from canteens. R. T. Binns and E. W. Levings both described beriberi in this camp. Some of the men from the desert fighting of 1942 were seriously ill, and a few died. Relief was difficult to give them, as the commandant refused to allow the use of invalid supplies held in the stores.

(b) *IN GERMANY*

Lieut-Colonel Le Soeuf (C.O. of the 2/7th Australian Field Ambulance) reported conditions as very bad in some camps. For example, in Crete, prisoner-of-war camps were allotted a diet chiefly composed of carbohydrate. At first the food was quite adequate, and after the first month or two a temporary supplement of fresh vegetables was supplied, but the sick were dependent mainly on the charity of the poor local Cretans, who gave them small quantities of milk and eggs. The diet was only of 1,400 Calories and some beriberi occurred here.

In Salonika famine oedema occurred in some prisoners; in Germany the dietaries varied greatly in different camps. In 1942 and 1943 there was a noticeable lack of protein, and in Dulag 183, for instance, the Australians arrived to find over 200 cases of famine oedema in hospital. The British prisoners received a starvation ration, apparently as part of deliberate policy. The German Military Authority claimed that the ration would have been increased but Red Cross food was available; nonetheless, during the periods when no Red Cross supplements were to hand no increase in the ration was made. Sometimes Red Cross stores were refused to men with oedema due to deficiency.

In Oflag 79, the diet was supposed to contain 55 grammes of protein and 1,800 Calories, but it did not, and oedema occurred in the men. The caloric value was reckoned to be 1,324, and the protein, totalling 46 grammes, contained only 7.1 grammes of first class protein. After some months on the German rations, officers at this camp noticed swelling of

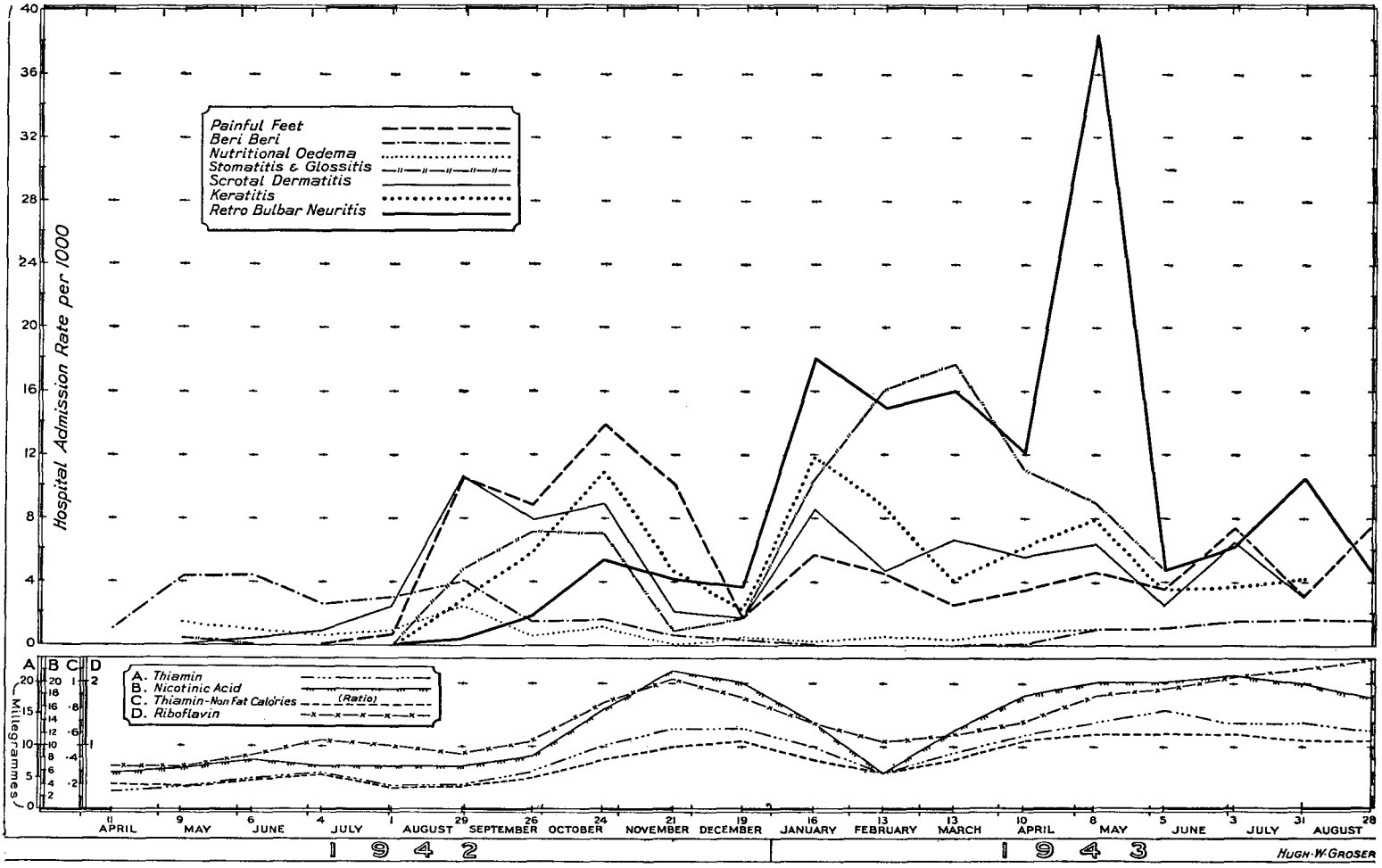
the feet and face. Two weeks after a delay in arrival of Red Cross food, general oedema and shortness of breath were observed, relieved later by an increase in the protein ration.

In March 1945 in a report on the camp conditions, Le Souef stated that there was gross undernourishment in the camp. At this date the ration given by the Germans to British and American officers contained 46 grammes of protein, 22 of fat and 233 of carbohydrate.

5. NUTRITIONAL DISTURBANCES IN PRISON CAMPS UNDER THE JAPANESE OCCUPATION

In a clinical account we are not directly concerned with administrative detail. Yet in describing the inroads of disease on the prisoners of war who fell into Japanese hands the effects of cruelty and neglect cannot be disregarded. With a curious lack of insight, and disregarding the greater working capacity of men given reasonable accommodation and nutrition, the Japanese wasted this labour force and allowed nutritional and infective diseases to kill the prisoners in thousands. Without the firm united stand and incessant struggles for better conditions by all concerned in the Allied forces, the results would have been even more tragic. The burden cast on the medical services was tremendous. Amidst all their labours they yet found time to record the clinical conditions of men with disorders of malnutrition, and this account of the medical scientific aspects of diseased states, largely owing to gross deficiencies of diet, is based on a series of carefully prepared reports, clinical accounts and diaries, mostly written in captivity and concealed till the day of liberation. Many of these are of high medical value in their own right, and in them the members of the medical services of the 8th Division tell their own story. The considerable space given to these descriptions is owing not only to their clinical worth but also to the sad fact that circumstances permitted an unusual experience which has some scientific value. To bring clinical pictures into relation with clear-cut dietary defects is always scientifically difficult and often untrustworthy. No such attempt is made here. The accounts stand on a basis of factual observation, with such suggestions about possible causes as may emerge from the story. They follow roughly the order in which they appeared in Changi, where continuous medical work went on for the whole period, and where good consecutive records were successfully kept, largely owing to the Acting A.D.M.S., Lieut-Colonel J. Glyn White. The order is therefore of chronological significance, which is pointed out by the chart constructed and kept at Changi.

After the capitulation in February 1942 it was evident that the Japanese ration scale was inadequate (Appendix 1) and a week's ration was issued to the troops from a six months' store held by the British forces. The chance of getting such necessary supplements such as meat and butter was slender, for they would have to be shipped to Malaya even if the Japanese would supply them. On the 10th March, Colonel A. P. Derham (A.D.M.S. 8th Division) gave a warning of the results of the

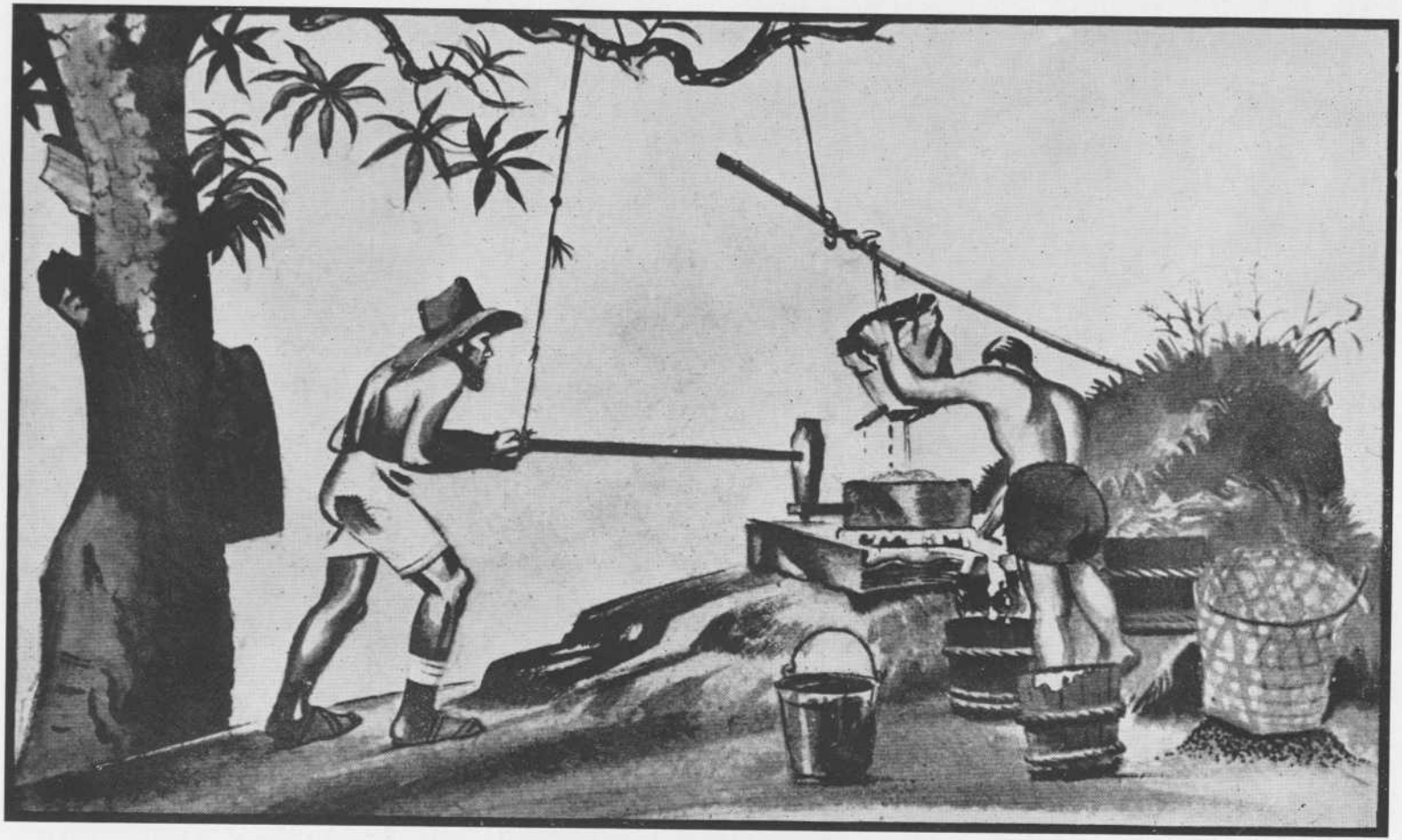


Incidence of clinical syndromes of malnutrition in Changi. (Drawn in Changi by Lieut. R. M. B. Strawbridge, R.A.E.)

proposed dietary scale and on the 15th, Brigadier Stringer (D.D.M.S.) prepared a letter sent by the G.O.C. Malaya to the Japanese Army commander pointing out the inadequacy of the diet, but without result. A nutrition officer (Major Burgess, R.A.M.C.) was appointed, and some months later a Nutritional Advisory Committee, on which the A.I.F. had representation. In March, beriberi had begun to appear in the forces in the Changi area, and by August, rapidly growing numbers of cases of deficiencies, chiefly due to lack of vitamins of the *B* complex had reached a peak. It is of interest to note that the Australians at first showed a higher incidence of these diseases; early in September 1942, 27 per cent of the British soldiers in hospital had deficiency diseases, but 42 per cent of the Australians in hospital. Little impression was made on the Japanese Army by repeated strong representations for dietary supplements, particularly rice polishings, soya and towgay (sprouted dhall), even though the figures were based on modern dietary tables drawn up by experts long resident in Malaya. Fortunately, the medical services of the forces had collectively an adequate library of medical scientific books and literature. Of course the necessity for the combined forces to help themselves was clearly recognised and from early days organisation was directed towards the buying, collecting and growing of fresh supplements of vegetables and other food, and those aspects of scientific research which would supply some of the much needed material of all kinds. By the later part of 1942, the A.I.F. services were producing an extract to supply extra vitamins of the *B* complex.

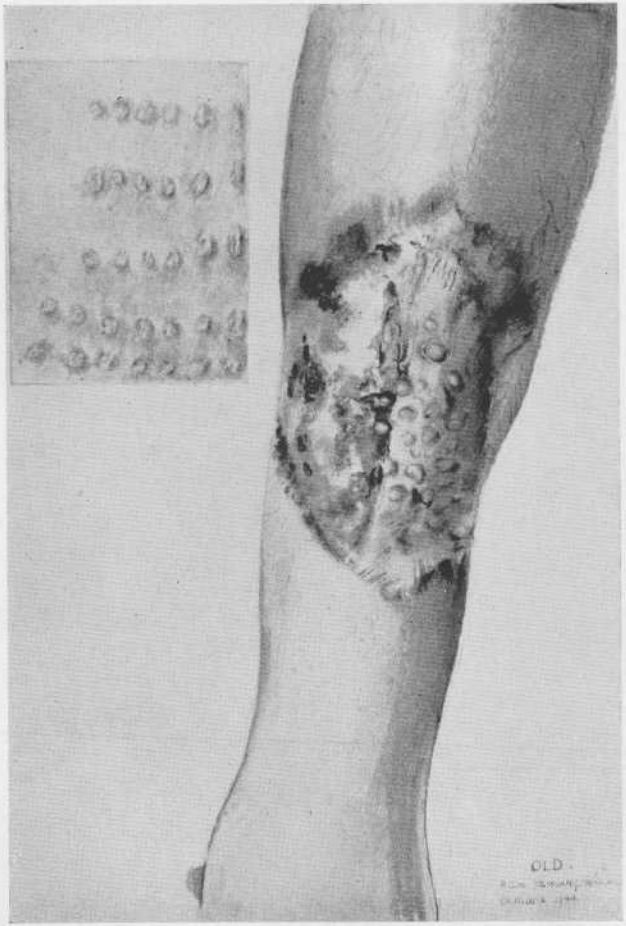
At first, with some reserves to fall back on and some Red Cross stores for use in the hospital, the nutritional state of the men, though showing some deterioration, was fair, considering the stress of the previous period of military action. Soon, however, the results of sub-standard feeding became evident, and with the added malign influence of dysentery, diphtheria, malaria and other infections, the numbers of deficiency states increased rapidly. By August, 10 per cent of the men in hospital had beriberi.

By the end of 1942, deficiency diseases of all kinds were common. Naturally, the incidence of these fell most heavily on the men employed in working parties. Some of the working camps were very bad indeed; disease raged in them and many men died. In others the conditions were less bad; they depended largely on the attitude of the Japanese commandants whose rank, experience and treatment of prisoners varied greatly. Some of these camps were relatively near the central concentration area in Changi, on Singapore Island, others stretched out in a long chain to Burma, Thailand, the Netherlands East Indies and Japan. Diets varied in each camp, and the amount of each foodstuff supplied daily was frequently well below the amount promised. Protests were in vain. Alterations in local rules, such as the institution of different scales for heavy workers, light workers and non-workers introduced imbalance more flagrant than ever. Non-workers included patients, so that a man who would be made more efficient by hospital treatment had his chance of speedy recovery



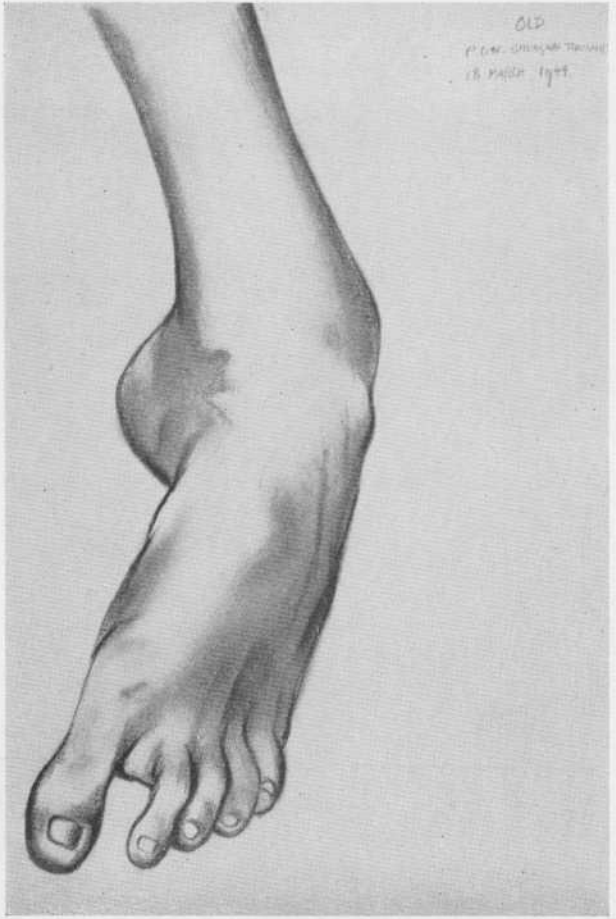
Milk from soya beans, P.O.W. camp, Tamuang.

(Drawn by A. G. Old)



(Drawn by A. G. Old)

Tropical ulcer—healing with skin grafting after excision.



(Drawn by A. G. Old)

Foot drop—neuritic beriberi.

reduced. It was often better for him to keep out of hospital, at the cost of his health. The following table contrasts the diets received for "light" and "heavy" workers in April 1944, and also shows the actual issues:

Item	Light duty Grammes	Heavy duty Grammes	Actual camp issue Grammes
Rice	265	400	275
Beans or maize	135	200	130
Vegetables	400	600	as received
Fresh meat or fish or	50	100	as received
Preserved or dried fish	25	50	as received
Sugar	20	20	18
Salt	20	20	17
Oil	25	25	25
Tea	5	5	4
Pepper	20	20	20

It was clearly the duty of the medical services to circumvent orders which inhumanly gave little chance of recovery to sick men; this they did by a system of pooling and when inspections frustrated this, by using repeated feedings. Dietary supplements were bought whenever possible, funds derived from officers' pay, N.C.O.s' pay and the pay of the working parties being used. Purchasing value fell off and prices rose steeply as the years went on. Red Cross parcels and other supplies when available helped to eke out the meagre ration, and for a time also, a loan of money from the Singapore representative of the International Red Cross helped greatly. Gardens were permitted and encouraged by the Japanese in the fixed camps, but the products were reckoned as part of the ration. Further complications in feeding were introduced by the constant movement of working parties. This affected arrangements in the Changi area considerably, especially when sick and weakened men returned from the sadly depleted working parties on the Burma-Thailand railway.

Special attention was given to hospital diets, especially in the fixed and semi-fixed centres. Supplements by local purchase were used, and eggs were bought from natives through a canteen, as long as this was permitted, or through an unofficial black market or from private owners of poultry. Poultry was also kept by some of the medical units with the help of the Japanese. The blessing of Red Cross parcels was applied to the amelioration of diets of men with debilitating acute or chronic disease, such as tuberculosis.

Certain periods and episodes during the weary years were highly significant with regard to deficiency diseases. Various syndromes were encountered in the early period of 1942-1943 when different clinical states due to malnutrition appeared in serial order. In the middle period, 1944, numbers of men had apparently contrived to exist with a lowered metabolism, though with a balance held precariously. This was due partly to loss of weight, which was usually substantial, but, whatever the cause, the incidence of nutritional disease at this later date was different both in

degree and character. In the final phase in 1945, conditions again became very bad, disease running a grim race with the prospects of relief by arms.

One of the striking features of the incidence of deficiency disease syndromes was their serial appearance. Thus various clinical pictures appeared in turn, overlapping to some extent in point of time, but really providing a series of epidemics which varied in nature and waxed and waned according to dietary changes and other more or less subtle metabolic influences. This epidemic feature of deficiency disease seen *en masse* is well known. At least it gave the medical officers an opportunity of studying the characters of each syndrome, and gathering information as its cause and its relief. This opportunity they seized fully and the knowledge thus gained was pooled. Full use was made also of the experience of medical officers attached to various components of the force on Singapore Island who were specially skilled in problems of tropical nutrition. A committee of physicians from the A.I.F. was formed to consider methods of investigation and treatment, and by November 1942 general agreement had been established among all physicians in the area as to the value of certain therapeutic measures. Opportunity was also given to individual medical officers to make intensive study of limited fields. Some discussion went on concerning the desirability of the use of control services in the assessment of methods of treatment, but the view of A.I.F. headquarters was that comparison of degrees of success attending various measures would be beneficial to knowledge and to the patients themselves.

Historically it is clearest to consider the symptom complexes as they appeared in the Changi hospital area, which drew patients from a fairly wide zone, including base troops and working parties on the island and neighbouring parts of the peninsula. A purely symptomatic classification was adopted officially there, with simple code letters to secure uniformity of description. A medical officer, Captain M. Woodruff, was appointed to coordinate the statistical side of therapeutic research, which was of course also valuable from the preventive side. The descriptive list included the following: burning hands, painful feet, encephalopathy, spastic paraplegia, peripheral neuritis (neuritic beriberi), cardiac beriberi, nutritional oedema, stomatitis and glossitis, buccal ulcers and palatal erythema, scrotal dermatitis, pellagroid lesions of the skin, tropical ulcers, keratitis (granular cornea) and deficiency amblyopia (the so-called retrobulbar neuritis). This does not represent the order of the appearance of these conditions in Changi. Deafness due to dietetic deficiency may be added, and the special variety of cardiac emergency which caused cardiac arrest and in most instances sudden death (*"shoshin"*). Later a fresh syndrome appeared, in which severe ulceration of the throat occurred, usually associated with neutropenia; this was called the "new syndrome" for purposes of discussion.

Certain clinical categories may be chosen as headings for descriptive purposes, and these will be discussed more or less in the order of their appearance, and as far as possible those believed to be of related aetiology will be bracketed. It will be realised that many, if not most, patients suffered

from several simultaneous deficiency states, and also from acute or chronic infections. The balance was always delicate, and an infection or an alteration of the ration consumed or absorbed, such as for example, excess of carbohydrate, could easily tip a patient from precarious equilibrium to frank deficiency disease. Deaths from dysentery, diphtheria, malaria or tropical ulcers were nearly always due in part to coincident malnutrition and deficiency disease. This was particularly so in the working camps, especially those in Burma and Thailand, where sick men were so often constrained to work. In Tamarkan, for example, in 1944, some 50 men suffered loss of a leg because of deep tropical ulcers, whose extensive nature was due largely to poor nutrition.

The times of appearance of the chief symptom complexes and period of their highest incidence and greatest intensity have been shown in the diagram on page 327. Cotter Harvey's table shown as Appendix 2 also sets out the average analyses of dietaries over the period of the Japanese occupation.

THE CLINICAL SYNDROMES

A. BERIBERI

The first sign of beriberi appeared within some six weeks of the capitulation. This had already been forecast by the medical advisers of the forces, by reason of the extremely poor dietary allowed by the Japanese Army. The first cases were seen in April among British troops. The type seen then was chiefly neuritic, and oedema was also found in some. Aids to treatment were insufficient and unsatisfactory, although a supply of vitamin *B*1 tablets was obtained from the Japanese. Later rice polishings were obtained as a dietary supplement.

By May 1942 the prisoners were suffering from loss of weight and energy, and the sick wastage had risen to 4.07 per 1,000 per day, a not inconsiderable figure in a force nearly 15,000 strong. There was urgent need for adequate protein and vitamins; even with such Red Cross supplies as were available the diet was deficient as shown in the accompanying table:

May 1942	
Carbohydrate	458 gms.
Protein	47 gms.
Fat	18 gms.
Calories	2,182
Non-fat calories	2,076
Calcium	0.127 gm.
Phosphorus	1.002 gms.
Vitamin *A*	231 I.U.
Vitamin *B*1	564.3 microgrammes
Vitamin *C*	2.5 mgms.
Riboflavin	0.879 mgm.
Nicotinic acid	7.625 mgms.
Thiamin/Non-fat calorie ratio	0.273

Some additions were obtained, bringing up the caloric value of the diet, raising the thiamin non-fat calorie ratio above the danger level, and

supplying less meagre amounts of the other elements of the *B* complex. It is difficult to assess the intake of thiamin and to correlate this with the onset of beriberi. The amounts taken varied, and probably even more so, the amounts absorbed. The optimum for men working in a hot tropical climate has been stated as not less than 500-600 international units, but for the purposes of treatment, 350 units a day was considered enough for a man of 60 kilogrammes weight receiving a diet of 2,000 Calories. It is widely held that the ratio of thiamin (in microgrammes) to the non-fat calories is significant as well as the actual amount of the pure vitamin available. Fisher pointed out in Nakom Paton and elsewhere along the Burma-Thailand railway the incidence of deficiencies of other components of the *B* complex was higher than beriberi, and doubted if an increased carbohydrate ration would precipitate the latter. But there are other complex factors to be considered, such as oedema due to lack of first class protein and the effect of this and other chemical and physical influences on cell metabolism. Occasional instances of beriberi were seen in the members of the force in Changi, but most of the patients came from the outside working camps. As time went on, fluctuations in the dietary scale occurred and with it deficiency diseases fluctuated also. Thus in 1944, a gross deficiency of vitamin *B* exposed the force to the risk of beriberi and when outbreaks of malaria and dysentery took place an epidemic of beriberi was produced. The T/NFC ratio in Changi dropped from 0.57 in January 1944, to 0.53, 0.43, 0.32, 0.25 and 0.23 in succeeding months, and during July was still only 0.23. Despite all effort to obtain supplements, the epidemic could not be averted, and included some cases of the cardiac type. At an early stage at Changi it was decided to classify beriberi under the following varieties: oedematous, neuritic, cardiac and those with encephalopathy. Here and in other areas certain difficulties of diagnosis were apparent. To what extent was oedema produced by thiamin defect and to what extent to protein deficiency? What objective signs should be demonstrable in the nervous system before neuritic beriberi could be recognised? What evidence of cardiac involvement was necessary before beriberi could be said to be of cardiac type? It was observed that disordered rhythm and dyspnoea were common in men with undoubted beriberi of other types, but were these sufficient proof of affection of the heart muscle? And finally, how could cerebral malaria, which might occur under the conditions prevalent in many camps, be distinguished from encephalopathy due to beriberi? Difficulties in connection with differential diagnosis of neuritic lesions have been referred to earlier, but these troubles were minor compared with those facing physicians working under conditions always difficult and often crude in the extreme. These problems will be dealt with serially.

B. NEURITIC BERIBERI

Prophecies concerning the inevitability of an outbreak of beriberi on the inadequate ration scale supplied by the Japanese were soon verified. By mid-April 1942, cases had been recognised and two sudden deaths

occurred from heart failure, believed after post-mortem examination to be due to cardiac beriberi. Experiments in yeast production were proceeding, but as yet insufficient supplements of this kind could be provided to protect the troops.

The first collected series of 50 cases contained 10 of the oedematous type, 13 of the neuritic, 2 of the cardiac and 25 combined. The predisposing factors were age, dysentery or diarrhoea, anorexia, with which the amount of food consumed was concerned. In nearly half the patients deep reflexes were lost, and in a greater number, sensation was impaired. Deep tenderness of muscles and tendons was found more reliable than surface loss of sensation for touch and pain. Oedema, when present, began in the legs in more than half, and in the face in about a quarter of the patients. Slight glossitis was sometimes seen, but no signs of other deficiencies at that time.

Though study of the clinical picture of beriberi at this early date is of some interest, it was not even then possible to distinguish symptoms of pure thiamin deficiency, if indeed such existed, from those owing in part also to protein and other deficiencies. There is indeed evidence that the Australian troops, perhaps owing to their normally larger meat ration, suffered more from beriberi than others during some of the earlier phases of their captivity. However, the coexistence of oedema with neuritic signs is recognised as a genuine part of the picture of beriberi, and there was every justification for the diagnosis to be made with confidence on this evidence. There was another good reason also. The Japanese would be more easily convinced of beriberi than some other deficiencies, owing to its prevalence at various times in their own population, and this argument, used as an incentive to obtain better rations, was more powerful than if confused by references to other deficiencies. As an official diagnosis nutritional oedema carried no conviction with the Japanese, in fact "inanition" and "malnutrition" were forbidden by them as diagnoses on death certificates.

In Changi and in the many other working camps, the symptoms of neuritic beriberi were found to be cramps, numbness, tingling, together with muscular weakness, dulling or absence of deep reflexes, an ataxic gait and paresis resulting in disordered posture, such as foot drop. An unsteady gait was often found and was due to affection of the dorsiflexors of the foot and the peroneal muscles.

In some areas, such as some of the camps endured by "F" Force, predominantly neuritic cases were rare, but a combination of oedema with hand or foot drop and anaesthesia of isolated parts like the lips, was common. There was no question that these were caused by beriberi. Although there was ample evidence of the connection between a low thiamin/non-fat calorie ratio and beriberi, a low intake of even such food as was available was in itself undesirable. It was found in some places that such a reduced intake of food ran parallel not only with poor nutrition but also with beriberi and oedema of various kinds. At Tanbaya an "eat your rice" campaign was started at a time when beriberi was increasing,

and this helped to break the vicious circle of poor appetite and lowered absorption.

Many instances could be quoted, too, of the effect of exertion. For example, in "H" Force the sustained effort of a long march under very bad conditions, after over a year of semi-starvation, precipitated an outbreak of beriberi in scores of men; during the next couple of weeks an extra issue of beans stopped the epidemic. Later, as the supplies of beans waned, beriberi again increased. These men were frequently oedematous and ankle and wrist drop appeared with dramatic suddenness. Acute and chronic cardiac beriberi also appeared. Some lives were saved by a small stock of capsules of vitamin *B*, and men urgently ill were given such dietary supplements as could be mustered from the common stock. In the working camps beriberi in some form was practically always present, and many of the men were insecurely balanced in this respect, only needing extra exertion, extra carbohydrate or an infection to produce frank beriberi.

In Japan experiences were similar, beriberi there was too often of sudden onset; neuritic or other symptoms might suddenly become manifest in men who up to that point had shown only a mild degree of gravitational oedema. In Java, in the early days of 1942, before rice polishings could be obtained, the staff of the 2/2nd Australian Casualty Clearing Station found about 90 per cent of patients had some form of deficiency disease. Some of the Dutch who were returned to the Changi area from camps both in the N.E.I. and Singapore Island suffered from advanced beriberi of all mixed forms, as well as gross oedema. For example, one very severe outbreak, including cardiac types of beriberi, was seen in a party of Dutch sent from Java to Rangoon on a grossly deficient diet. The treatment of beriberi of the neuritic type, associated as it generally was with some degree of oedema, was of course primarily a problem of supplying a reasonably adequate diet reinforced with thiamin. The prospects of doing this successfully varied greatly with local conditions and supplies. For example, the following figures taken from a special report by Bruce Hunt on "F" Force, shows the difference between the Changi area and the various camps from Konkoita to Tanbaya. The T/NFC ratio of the food at Changi was below 0.2 in March and April 1942, but rose in June to 0.345, just above safety level, and though for the next three months it was below 0.3, it rose to 0.479 in October and remained at a safe level for nearly eighteen months with the exception of two very bad months early in 1943. After this, steady deterioration took place, and for the last four months of captivity till August 1945 the ratio was not much over 0.2. It will be seen then that men with beriberi had a reasonable chance of relief in hospital in Changi. But in the Konkoita area, the T/NFC ratio was never above 0.2, and the same applied to all the camps occupied by "F" Force till after they reached Tanbaya, where the figures actually rose to 0.43 and 0.61 in October and November 1943. How could a man with beriberi be given the treatment he needed? As Hunt remarked: "The real tragedy lies in the fact that much of the disease is really curable

if proper foodstuffs and drugs are available in sufficient quantity". The figures for Tanbaya show that of a camp population of 1,500 to 1,600 during September-October 1943, the percentage of these men suffering from beriberi was from 31 per cent to 39 per cent. In August-December 1943, 413 deaths occurred from beriberi alone, and 477 others from beriberi and other coincident causes.

Where possible, severe and extensive affections of beriberi were treated by adequate nutrition; and in spite of the attempt by the Japanese to impose a still more inadequate ration on sick men, the standard attained by the hospital staffs in settled areas was reasonable, judged by the prevailing conditions. Thiamin was supplied by giving marmite,[1] two drachms by weight, up to three times a day, yielding perhaps 100 units, or by 2 ounces of rice polishings daily. Where injectable vitamin *B*1 could be obtained up to 3 to 5 ampoules of 10 milligrammes were given daily. Paralysed limbs were splinted to prevent deformity; after a time even appliances, if needed, could be made in Changi, and re-education in movement and in walking was carried out.

In Changi, improvement in the neuritic signs was noted after two to three weeks, and cure might reasonably be expected within several months.

C. NUTRITIONAL OEDEMA

The problem of oedema is not unaptly considered in immediate relation to beriberi, for although neuritic signs and oedema were frequently seen in the same patients, they were not necessarily due to the same cause. A diagnosis of oedematous beriberi was convenient, even though it was not aetiologically correct. The question of cardiac involvement may be conveniently put aside for the moment.

In all areas where gross oedema was encountered, the same conclusion was reached, as it has many times and in many places before, that the chief cause was hypoproteinaemia. Even in April 1942, oedema was a striking feature in some patients in Changi, and evidence of cardiac affection in others perhaps emphasised unduly the seriousness of oedema as a symptom. But as experience grew it became apparent that general anasarca might exist without cardiac failure and without neuritic signs or symptoms. Fisher described a small outbreak among the men of an Australian medical unit at Tavoy, in which oedema chiefly of the face and the lower extremities was a prominent feature.

Later, more extensive oedema was observed in other patients who, in spite of conspicuous waterlogging, were breathless only from mechanical causes and showed satisfactory cardiac and renal function. Naturally they had oliguria, but the urine contained no albumin. Elsewhere similar states were found, and these were believed to be due to a protein deficiency in the diet; in other words, famine oedema. Treatment with vitamin *B*1 was without effect, but feeding with a high protein diet, when this could be

[1] Where mention is made of marmite this will usually refer to local substitutes, not necessarily "Marmite" the proprietary product.

obtained, relieved numbers of patients. Naturally such a diet was difficult to provide, and it could be tolerated for only a short time by men with long standing malnutrition. Numbers of these died from intercurrent infections, some succumbing to gangrene starting in infected ulcers. Unless diuresis was started promptly by this and other measures, it was found best to cease treatment for a short time and resume after a rest. Even the successful drainage of oedema fluid from the body was not always calculated to restore the confidence of either patient or doctor, as the extreme loss of subcutaneous fat became evident when an emaciated frame appeared, a ready prey to other diseases.

Dysentery was a common prelude to these severe oedematous states. As a result of observation of the results of gastro-intestinal disease in malnourished men, preliminary starvation was discounted in the treatment of dysentery and the patients were fed within limits of their tolerance and the possible dietetic resources.

The clinical manifestations of oedema due to faults of nutrition varied from slight pitting of the ankles to the most extensive anascarca. Though gravitational influences were evident, the distribution of the fluid conformed rather to that seen in nephritis. The face was involved early, and was often swollen at the same time as the lower parts of the legs. Ascites occurred with the severe types, but the other serous membranes were seldom affected, and then in the later stages. Sometimes weakness of the limbs was observed, but this was no essential part of the picture. A coincident neuritic beriberi occasionally caused some of the usual palsies. Hunt described adductor paresis of the laryngeal muscles, usually on the right side. Oedematous parts were sometimes anaesthetic, and sometimes affected by paraesthesia; tenderness of such parts, occasionally seen in other mechanical and chemical types of oedema, was not described. Captain R. M. Mills raised the question of a nephritic element in some of these oedematous patients, such as were seen in "F" Force. He suggested the possibility of a reversible symptom complex of which one cause might be disturbance of renal function. The men in "F" Force were universally infected with malaria, and were constantly on the verge of beriberi, and other avitaminoses. Mills described a sequence in which men with slight general oedema had abdominal distress and pain, passed scanty brownish ("tea-coloured") urine, and had malaise with slight fever. The administration of quinine controlled the fever and polyuria was established, with recovery in favourable circumstances. The observation that men dying with relapsing malaria and serious malnutrition were found to have subacute or chronic renal changes, suggested the possibility of more common, though unrecognised, grades of nephritis. Harvey, on the contrary, pointed out that the malaria centre in Changi treated over 1,200 patients up to the end of 1943, but saw none with oedema, and that oedema in "F" Force disappeared when better diet and more adequate quantities of thiamin were obtained. It must of course be admitted that the conditions were much worse in many of the Burma-Thailand camps than on Singapore Island, but, though the possibility of impaired renal function was more

likely in the former than in the latter, it does not seem probable that nephritis was *per se* a significant cause of oedema. Again, it must be admitted that descriptions of the disturbances of renal function, recognised as occurring in some forms of malaria, are based on very different circumstances.

It may be noted without suggesting any causal relations that a very severe form of beriberi was seen in Dutch civilians who had been working very hard in a hyperendemic malarious zone; they had gross general anasarca and X-ray screening showed cardiac enlargement. Some of these severely ill oedematous patients had a raised blood pressure during the period of oliguria and intense oedema.

As an adjuvant to treatment mercurial diuretics were found to be very useful to initiate or accelerate diuresis. "Mersalyl" gave good results, but a Japanese substitute was found to be ineffective and toxic. Ascitic collections of fluid sometimes required tapping, and rarely paracentesis of the thorax.

One feature noticed in "K" Force in Thailand was the greater frequency of "oedematous beriberi" among men who had been isolated alone or in small groups in poor coolie camps. Enlargement or coalition of these groups meant more organisation, which in itself enabled supplements to the rations to be obtained more freely. In "J" Force in Japan gross oedema was not at all uncommon. It was frequently of sudden onset and of the usual pattern. Suppression of urine was a frequent feature; it was sometimes complete for 48 hours, though more usually only a few ounces would be passed in 24 hours. Free diuresis seldom appeared before about a week.

Towards the end of the period of captivity, particularly in the last six months, the number of patients with oedema in Changi gaol area increased. They had been subjected to a semi-starvation diet for some time, the ration steadily becoming worse. There can be no question that these oedematous states were due to malnutrition, chiefly lack of protein, and possibly in part also to vitamin deficiencies. It would be rash, however, to conclude that these are the only possible factors at work in the bodies of men subjected to privations so comprehensive and prolonged.

D. CARDIAC BERIBERI

In the section dealing with cardio-vascular disease the story of the late effect of attaching the diagnostic label of cardiac beriberi has been told. Different opinions were held by different medical men in Singapore, Burma and Thailand as to what could be justly called "cardiac" beriberi. Their arguments bore fruit in producing a sound and balanced outlook on the use of the term, and on the handling of men who had cardio-vascular symptoms due to malnutrition. On the one hand it was observed that men with well marked or severe neuritic beriberi, who usually had some oedema, usually also had some disorder of heart rhythm or anomaly of the heart sounds, even though no enlargement of the heart could be detected by fluoroscopic examination. At the other extreme were men

with general oedema and signs of cardiac failure with demonstrable enlargement of the heart. In a different category were men who died suddenly, and usually unexpectedly, or who had attacks of cardiac arrest. These were beyond doubt due to affection of the heart itself, but the problem was not diagnostic but rather aetiological. No great difficulty arose in recognising the beriberi heart in circumstances permitting adequate investigation, as in the Changi hospital area. Further, the steps to recovery could be traced convincingly by watching the heart decrease in size under the influence of adequate diet containing ample thiamin. The pathological parallel with the myxoedema heart can be drawn here, which serves to recall how excess fluid not only infiltrates the fibres of the heart's substance, but also embarrasses the inner metabolism of the striated muscle fibres themselves. But where no gross hydroptic state of the heart could be demonstrated, the question arose of the signs and symptoms which would justify the diagnosis of cardiac beriberi. The advantage of this label was that it gave a better chance of impressing the Japanese with the dangerously low level of the diet; the disadvantage, that it created alarm in the patient's mind, and unless he was progressively exercised readily became an invalid and acquired a cardiac neurosis. The details need not be retold here, but this was well illustrated in some of the men who returned from "F" Force, fatter than their fellows, unable, as they thought, to get about, or in some cases to get up, and unhappy in the belief that their hearts were organically spoiled. Fortunately the opportunities for full investigation restored their confidence, and encouragement to resume activity cured them. Major Bruce Hunt, in a long and careful clinical study in Thailand, compiled a list of cardio-vascular symptoms in beriberi. These comprised palpitation, with a consciousness of cardiac unrest, paroxysms of rapid heart action, irregularity, due usually to frequent extrasystoles, fatigue, shortness of breath, sighing, a feeling of oppression in the chest, sometimes amounting to pain, usually dull, and felt towards the left side below the nipple, dizziness and faintness, loss of sleep and appetite, and apprehension. Pulsations of an overacting heart were seen in the neck, chest and epigastrium. At Kanburi he carried out extensive observations, and in a series of 100 men detected signs of enlargement of the heart in 26 per cent, 20 per cent involving the left side. These observations were subject to the fallacies inherent in estimating the size of overacting hearts in thin people. Long sounds, triple rhythm, splitting of sounds and soft systolic murmurs were common. Cotter Harvey, C. R. Furner and W. A. Bye, physicians at Changi who reviewed some of these men who survived to return to Changi, and who examined many men with beriberi in Changi, often noted similar disturbances of sounds and rhythm, but did not consider that they truly had cardiac beriberi unless signs of enlargement and failure were present. Fisher arrived at similar conclusions in Nakom Paton. He reviewed a number of patients labelled as cardiac beriberi, who had been the subject of comment by a Japanese medical officer, and reported that their symptoms were due either to beriberi in the general sense, to debility from malnutrition, to other deficiencies

or to effort syndrome. This last, in others words a cardiac neurosis, was due to the impression given to many of the patients that they had diseased hearts. He undertook special training of 90 of these men and practically all were returned to work by the end of four months without any untoward effects being observed. After all, it is a matter of terminology. There is no doubt that it is better not to implicate the heart in the diagnosis except with very good reason. It must be remembered, too, that the men in the Thailand railway camps were in a lamentable state of semi-starvation and overwork; in brief, the death rate of "F" Force tells the story. It will readily be conceded that, though the diagnosis of cardiac beriberi may sometimes be technically questioned, the incidence of cardio-vascular symptoms in relation to severe beriberi was considerable. It is not surprising that apprehension was common in men who had subjective circulatory symptoms. The combination of extra-systoles and mental anxiety is well known quite apart from neuroses; indeed it would be hard to find a better example than the showers of ectopic heart beats observed in sufferers from prolonged travel sickness. It is not without interest to observe that Hunt reports that sudden deaths occurred in some men after exertion or fatigue, in particular after the discomfort of rail journeys. Auricular fibrillation was very seldom seen in beriberi in the larger settled areas, but in some of the severely ill men in the camp hospitals it occurred and was of evil omen.

Sudden deaths, already mentioned, and briefly discussed in the section on cardio-vascular diseases, were without doubt connected with malnutrition in many instances. Such happenings have been observed in the subjects of starvation. We know that a man with some stenosis of the coronary arterial system may drop dead and that no clot or other gross mechanical cause may be found *post mortem*. It seems logical to postulate a sudden dysfunction of the junctional tissues of the heart similar to the sudden interference with cardiac conduction or contraction due to nutritional disturbance. These unexpected deaths were only occasional in Changi in 1942, though one occurred within a month of the capitulation. When the depleted "F" Force returned from Thailand in 1944, there was some increase in the frequency of these emergencies, accentuated by the physical deterioration noticeable among the men. This rise in the number coincided with increased incidence of oedema and of beriberi. The peak in numbers was only six among a camp strength of 16,000, and the total number remained small. Nevertheless the nature of these accidents was very disturbing, especially as those noted in the hospital area were not associated with exertion. Attacks of ventricular arrest were also seen, resembling the Stokes-Adams syndrome. Some men recovered after repeated attacks, some after injection of adrenalin into the heart, others spontaneously. Thiamin was given to these men in repeated large doses. The clinical history did not suggest any reason other than those connected with nutritional defects. Most of the men were young and not severely ill.

In one or two instances autopsy indicated failure of the right side of the heart, but as a rule no cause was revealed. The effect of quinine was

suggested as possibly relevant, as a number of the men had been taking this drug, but there was nothing to support this. The enormous number of men, sick and well, who have taken quinine and who have had it injected intravenously without trouble, disposes of it as a possibility.

Quite apart from this small but important group of unexpected cardiac accidents, a point of some interest in cardiac beriberi was its occasional suddenness of onset. An example may be quoted of one man who had oedema of the legs and face. Orthopnoea appeared with striking speed, and X-ray examination showed that the left and right ventricles were dilated. The heart sounds showed rapid variation in their character and rhythm and there was positive clinical evidence of left ventricular failure. This man recovered rapidly on administration of vitamin *B*1.

Breathlessness was an important feature of cardiac beriberi; it was usually worse at night. Pulmonary oedema was sometimes observed, and occasionally periodic breathing. Although precordial pain was unusual, tightness was felt in the chest, no doubt accentuated by collections of ascitic fluid. Clinical estimation of the size of the heart was often found difficult, and was not infrequently incorrect when checked radiologically. In Changi left sided enlargement was much more common than right sided; similar findings were made by Hunt in Thailand. It is important that no conspicuous degree of dilatation was ever found in the absence of oedema, though sometimes the heart appeared of normal size even in the presence of oedema and of signs of circulatory failure.

Systolic murmurs were commonly observed and the heart sounds were often reduplicated. Gallop rhythm was sometimes observed; in a few instances the blood pressure was beyond the normal range; sometimes this was transient only and sometimes it persisted for some weeks. Fortunately the death rate of patients in fixed hospitals like Changi was low. Diuresis usually marked the beginning of recovery, and once the urinary output rose, oedema generally subsided rapidly. Where radiological examination was possible, the heart could be observed to diminish in size and generally return to normal within one or two months. The amount of cardiac enlargement due to dilatation often subsided quickly. Purified thiamin was not always available for treatment. The concentrated preparation was given when available, but many patients made a good recovery with rice polishings only. A liquid extract was generally administered, about half a pint per day; the local experts who produced this extract estimated that each pint contained over 2,000 international units of vitamin *B*1. In addition as generous a diet as was possible was allowed. Some of the patients admitted from the working camps on Singapore Island or other areas close to a settled hospital, although suffering from an undoubted cardiac beriberi, were not always severely ill. These men responded well as a rule to rest in bed and other appropriate treatment.

Some observations were made in Changi also on beriberi in relation to infections such as dysentery and malaria. The effect of many infections in precipitating beriberi is, of course, well known, but in some instances the onset of dysentery or recurrence of malaria induced a return of

cardiac symptoms. This did not always appear and in general, patients who recovered from cardiac beriberi, did not appear to have any residual debility, though of course in the prevailing circumstances many other dangers awaited them.

Occasional instances were seen of cardiac beriberi occurring in the subjects of organic heart disease. Naturally amongst army men there were few of these, in whom the combination of a previously established rheumatic valvular disease and cardiac beriberi was observed. It is not surprising that breathlessness and pulmonary oedema were easily produced. In other words, a lesion such as a mild mitral stenosis was a predisposing factor to failure in a heart affected by thiamin deficiency. Review of patients who had had cardiac beriberi was possible in a number of instances and it was found that the recovery of the heart was as a rule complete. In this connection the question of the significance of extra-systoles during or after beriberi was examined. Where this irregularity occurred in a patient showing other signs of active beriberi, other changes of the heart were generally also observed, but other patients, after recovery from beriberi, had persistent or occasionally recurring irregularities due to extra-systoles without any sign of organic disease. It would seem unlikely that, having regard for the general effects of malnutrition, these findings were of any particular significance in themselves. Some observations were made to see if the administration of rice polishings would effect such irregularities, but no change was observed. Reference has been made elsewhere to a report made by Major Uhr on the radiological aspects of beriberi heart. A very distinct difference was noticed in patients who came from the camp area and those who came from outside camps. This of course was due to the very bad conditions in some of the working camps which produced deficiencies of a much severer order. The latter were difficult to examine because of the great amount of oedema fluid. No films were available and screening alone could be used. The heart/lung ratio was estimated by comparing the maximum transverse diameter of the heart in moderate inspiration with the widest diameter of the thorax; a constant target-screen distance was maintained and also constant milli-amperage and kilovoltage. Major Uhr found as the result of three years' observations that the "normal" heart there was smaller than usual. The average heart/lung ratio was 1:2.5. In a number of patients it was possible to demonstrate a substantial enlargement, usually of the left ventricle, which was restored to average size by successful treatment. Twenty-three out of 35 cases showed enlargement of the left side. Oedema of the lungs was not always demonstrable and fluid in the pleural cavity was uncommon. A feature commonly seen in the acute condition was broadening of the mediastinal shadow.

E. ENCEPHALOPATHY

Occasional instances were seen of cerebral seizures conforming to the descriptions accepted as characteristic of encephalopathy due to dietetic deficiency. Some of these occurred during the first few months after the

capitulation. This is consistent with the epidemiology of cerebral beriberi, which is known to occur rather in the first stages of exposure to thiamin deficiency. Cases of encephalopathy have been reported in British soldiers in Changi, and post-mortem examination showed haemorrhagic lesions in the mid brain such as described by Wernicke. In another fatal case reported from Malaya the lesions were in the *pons,* but the cause was not clearly established. The diagnosis of thiamin encephalopathy may be confused by the coexistence of deficiency of riboflavin and nicotinic acid or by cerebral malaria, though the post-mortem findings in the latter should be easily proved. The later onset of other deficiencies in communities on an insufficient diet makes encephalopathy of earlier occurrence much more likely to be due to thiamin. This early appearance of cerebral forms of thiamin defect applied not only to Singapore but to Java also. Here Major R. H. Stevens reported cases of sudden illness in which patients complained of headaches, became stuporose and had convulsions. Lumbar puncture showed the fluid to be clear, but under pressure. The cause was believed to be cerebral oedema due to deficiency. In various places affections of the cranial nerves were occasionally seen, particularly diplopia, but it was not easy to decide whether these manifestations were due to deficiency of thiamin or of another vitamin, such as riboflavin. For example, a man with neuritic beriberi showed signs of laryngeal and palatal palsy, had diplopia and incontinence of urine with high fever. The diagnosis made was cerebral beriberi, but intercurrent infection of the nervous system was possible. Similarly, affective changes, vomiting, and ocular muscle palsies may be seen in patients with neuritic beriberi, but it does not follow that they are necessarily due to insufficient thiamin. A. C. P. Campbell and W. Ritchie Russell have pointed out that oculomotor disturbances are the most common cranial nerve sign in thiamin encephalopathy, but that diplopia and paralysis of conjugate movements may be due to combined deficiency of thiamin and nicotinic acid. Similarly ataxia and other signs of lesions of the lateral and posterior columns may occur also in beriberi but it does not follow that the cause is single. However there seems little doubt that there was a relation between the early encephalopathic states seen in Singapore and elsewhere and the known lack of thiamin in the diet.

F. SCROTAL DERMATITIS

One of the earliest deficiency states to appear in Changi was scrotal dermatitis. As usual, a few instances were seen in the beginning, heralding an epidemic outbreak beginning in July. Paralleled by the appearance of lesions of the mouth and tongue and by painful burning feet, this condition attained its highest incidence in August. Many medical officers have described it, a typical description is that of Major B. L. W. Clarke. He recognised four stages: (i) erythema with vesiculation, invariable symmetrical in distribution, (ii) cracking with weeping, (iii) extension to the penile and other neighbouring skin surfaces, and (iv) oedema and patches of ulceration, with intertrigo, and spread to the anus. Patients requiring admission to hospital needed 6 to 8 weeks for reasonable

recovery, and the lesions readily broke down if hard work was resumed too soon. Radical changes of diet had been imposed on the men, who were only having 15 ounces of rice a day and a few ounces of meat a week. In some areas the incidence was later, as for instance, in a force which arrived in Thanbyuzayat in October 1942. A few men had red scaly or raw weeping scrotal skin, a little later a few had painful feet and failing sight. The numbers rapidly increased to hundreds, and in June 1943 there were 400.

In Changi, aggravation of the lesion was often seen following the application of irritating dressings. Once again the old lesson had to be learnt about an inflamed skin; red palm oil with a trace of zinc oxide was usually found suitable. Gunther, who observed large numbers of men there, found in about 100 men a uniform bright pink appearance of the scrotal skin which was non-rugose, smooth and shiny, thickened and inelastic. Many of these men had stomatitis or glossitis, and preputial lesions were seen too, sometimes with considerable swelling. The most effective treatment was marmite, which cured or improved all on whom it was used; 86 per cent improved on yeast within a week, and 67 per cent on rice polishings, but after two weeks only 47 per cent who had yeast were cured and 29 per cent of those taking rice polishings, whereas by that time 82 per cent were cured by marmite.

Clarke tried fruit juices, yeast, vitamin *B*1, vegetables and peanuts, without much benefit, and found marmite, and to a lesser extent vegemite, effective, though more than two drachms caused diarrhoea. Rice polishings had little effect, but these were often dirty and impure. The arrival of Red Cross stores made a distinct improvement. Half doses of ultraviolet light gave some relief. Gunther analysed a series statistically at Selarang, and his results confirmed the findings that success in treatment was quicker and more uniform with marmite than with other supplements.

This was a most uncomforable disorder, made worse by the climate. Itching was persistent, worse at night and exaggerated by friction. Chemical irritation caused chiefly by anti-tineal preparations caused added inflammation. In Clarke's series, 75 per cent of the men with scrotal dermatitis had glossitis, 50 per cent palatal erythema and 25 per cent burning feet. Some also had cracks behind the ears and sticky conjunctivitis, and small but increasing percentages had granular cornea. The symmetry of the scrotal lesions was a constant feature, but the raphe was uninvolved. In advanced cases, pain was considerable, and spread to the cords which were swollen and tender. Now and then diphtheria occurred as a complication. Usually it could be recognised by its yellow membrane, with the added symptoms of pain and toxaemia.

In Changi, after April 1943, a few severe cases of scrotal dermatitis were seen, partly owing to the shift of the population from the area, but partly also to the increase of supplements to the diet provided through the endeavours and insistence of the force itself.

In numbers of working camps this lesion gave similar trouble and in general its appearance and severity were paralleled by the presence or

absence of an adequate amount of vitamin *B* complex in the diet. In Kami Sonkurai from August to November 1943, "F" Force, though under bad conditions, was relatively free from painful feet and scrotal dermatitis. This was probably due to the regular consumption of "jungle stew", compounded of leaves of wild pumpkin and other plants, also eaten as spinach.

In Changi, too, towards the end of 1942, the addition of rice polishings and the improvement of the general diet were apparently responsible for the virtual disappearance of scrotal dermatitis. In the later periods, during 1944, after serious falling off in the ration scale for some two months, an epidemic broke out again of a composite kind in which scrotal lesions were prominent. At this time, scrotal dermatitis which had previously been seen as a predominant, though by no means a single, lesion, appeared with a variety of other deficiencies due to lack of riboflavin and niacin. This was the experience in the worst working camps too, where multiple deficiencies begot multiple diseases. Thus, in Thailand, Hunt records seeing all the lesions of eyes, skin and mucous membranes that could occur. The resultant disability was often not severe, but as Hunt correctly reported at the time "much more trouble may be anticipated from this source unless the diet of the troops is substantially enriched in the near future by substances containing the *B*2 complex (riboflavin and nicotinic acid)". Most of "K" Force was also effected by scrotal dermatitis, glossitis and stomatitis in 1943, but it is interesting that the severe forms of these diseased states such as occurred in Changi in 1942, were not seen.

In "J" Force after a year in Kobe, Japan, a review by Captain Boyce showed that scrotal dermatitis was the commonest deficiency symptom with the single exception of the disorders of vision. In this force over 60 per cent of the complaints causing men to seek medical relief were due to dietary deficiency.

G. LESIONS OF THE LIPS, MOUTH AND TONGUE

Bracketing the lesions affecting the lips, mouth and tongue is merely a convenience in clinical description, for it does not imply that all these were due to the same cause.

Cheilosis and Angular Stomatitis

The lips were sometimes red and swollen, they might become dry and fissured, and weeping or scabbing might be present. Extension of fissuring and inflammatory changes occurred later, and might even involve the skin on the face up to half an inch from the muco-cutaneous junction. The angle of the mouth was frequently involved, fissures formed and invasion of skin was likely to occur at this point. In severe affections, possibly aggravated by some low-grade infection, a fungating mass might form on the red portion of the lip.

Buccal Lesions

The mucosa of the cheeks and palate was sometimes in discrete lesions. These might be white thickened plaques, seen chiefly along the line of

occlusion of the teeth, and not infrequently blebs filled with sanious fluid formed on the cheeks and palate. Occasionally the lesions would spread to the anterior faucial pillars and in later stages ulceration occurred.

Erythema of the Palate and Pharynx

Palatal erythema was distinctive enough to be recognised as an entity, and sometimes spread to the pharynx. The tissues became swollen and tender and sensitive to heat, and swallowing became painful. Associated glandular swelling in the neck was also seen.

Glossitis

This term is only used loosely, for all the changes seen in the tongue were not truly inflammatory. Lesions of the tongue appeared later than those of the mouth, but it did not always follow that a complaint of soreness of the mouth was due to lesions of the mouth, as investigation sometimes showed that it was really the tongue which was sore. A glazed red atrophic tongue was a variety frequently seen, but this was not an early stage. The first abnormal appearance was leucoplakia, after which the tongue became swollen. The papillae were involved in this change and became enlarged. The next stage was fissuring, though in some series no fissuring was seen. Fissures were sometimes wide, and ran more longitudinally than transversely, but also extended to the edges. These changes sometimes ran in cycles: return of the papillae would initiate healing, but relapse would then occur reproducing the glazed painful condition of the tongue.

Hypopharyngitis

Inflammatory changes sometimes extended as far as the lower part of the pharyngeal mucosa, and even to the vestibule of the larynx. Rarely the arytenoids were involved and even oedema of the glottis occurred. This condition was a later sequel of the lesions described above. It gave rise to great discomfort and pain and was sometimes complicated by a superadded streptococcal infection with enlargement of the cervical glands. Toxic symptoms were associated with this condition. Such severe manifestations were relatively common towards the end of the first wave of deficiency states in the later part of 1942.

More will be said later of the place of these tissue changes in the general picture of deficiency disease, but they can be conveniently regarded as readily recognisable manifestations of lack of certain elements of the *B* complex, apart from thiamin. These appear to be riboflavin and nicotinic acid.

H. PAINFUL FEET

The syndrome known as painful feet or burning feet has been described from many places where there has been dietary deficiency. It is sufficiently distinctive from its clinical aspects to stand as an entity although it appears to have been sometimes a stage in the development of other deficiency states. This condition appeared early in the prison camps. In Changi it was common amongst members of the A.I.F. during June and July 1942 and

reached its peak from August till October 1942. It recurred in 1944, following another period of bad diet, but on this occasion the symptoms were less severe. It caused great disability, particularly during its first visitation. An epidemic which occurred in Manchuria among prisoners of war was also severe and here it would appear that the extremely severe winter accentuated the symptoms. The age of the patient seemed also to bear some relation in the severity. In 100 men carefully investigated by Captain M. Woodruff, who was acting as medical research officer for the A.I.F., about three-fifths of the men were fit for duty, one-quarter for light duty only and the remainder were unfit for any work. The most troublesome symptom was a pain usually described as burning in the feet, mainly in the metatarsal area, extending to the toes and also to the ankles, heels and soles, and sometimes to the calves. A curious finding was observed in two men who had both had one leg amputated some months before for wounds received in action. Both of them complained of feeling pain in both feet. The pain was dull rather than sharp, but there was, particularly in 1942, a persistent burning quality in it which was very hard to tolerate and as the symptoms were usually worse at night, loss of sleep was common.

Affected men bathed their feet or rubbed them to get relief and commonly walked about owing to the difficulty of remaining still, particularly at night. Some suffered from "starts" or spasmodic jerking of the legs during periods of rest; some tried immersion in cold water to gain relief and some of the men in camps in Manchuria even exposed their feet to the bitter cold or put them in snow, a practice which naturally was forbidden.

The hands were often similarly affected, but to a lesser extent. The general condition of the men was the same as that of the other prisoners, but loss of appetite was noticed to be common among them; so too was mental depression. This may have been due to the constancy of the complaint and to loss of sleep, but it is possible that it had some further significance. A large percentage of the men, rising to some 80 per cent, gave a history of some other form of deficiency attributed to lack of *B*2 complex. Thirty per cent of the men with painful feet at Changi had stomatitis and in some other areas the percentage was greater. Oedema and neuritic signs in the legs were unusual in those suffering from painful feet, only about 8 per cent in 1942.

During a review of the men in this area, the sequence noted was beriberi, affections of certain of the exposed areas of the skin and mucous membranes, and painful feet. It was shortly after this that deficiency states which affected the eyes began to appear.

Examination showed the feet and legs to be reddened, but although the patients experienced the sensation of heat, the skin was not necessarily hot and more usually felt cold to the touch. Superficial tenderness was common; arterial pulsation was good and although clearly seen, was not abnormal. Sweating was common; the skin often felt clammy and nutritional changes occurred in the nails, which became ridged and brittle.

None of the men complained of deep pain or muscle tenderness. A considerable proportion of men had exaggerated knee and ankle jerks.

Clonus and other signs of disturbances of the pyramidal tracts were sometimes seen in patients who afterwards showed progressive symptoms of spinal cord affection. Twenty-three per cent of one series had increased deep reflexes, but ankle clonus was found in only a few of these. The appearance of this sign did not necessarily indicate that further nervous changes were pending. A small percentage had sluggish reflexes which of course were of no special significance. In some instances there was evidence of impaired circulation in the feet, particularly in their slow reaction to temperature changes. The condition bore a resemblance to that described under the name of erythromelalgia. The cause of this condition was undoubtedly a dietetic deficiency, and some of the evidence supported the belief that it was due to a vascular affection due to insufficiency of part of the vitamin *B* complex, probably riboflavin.

The sequence of this clinical state with reference to other clearly differentiated conditions was constant in the areas in which it appeared. For instance at a combined meeting of Dutch and Australian medical officers at Bandoeng in October 1942, it was noted that *tinea cruris* had been prevalent; then scrotal dermatitis appeared which failed to respond to local treatment. At the same time lesions of the mouth and tongue were observed pointing to the existence of vitamin deficiency. Yeast or extra food improved these conditions, but within a month men began to complain of burning feet, and soon this reached epidemic proportion, 10 per cent of the camp strength being attacked. Shortly, ocular troubles appeared in about one-fifth of the men with painful feet. This is only one of many similar experiences and it appears to incriminate lack of part of the vitamin *B* complex, probably that including riboflavin and nicotinic acid.

In Changi it has been pointed out how the occurrence of these disabilities followed the very poor diet of the early period. The same thing happened again in 1944, when the soya bean and other supplements used in the diet were not available and maize was substituted. This was possibly objectionable in itself, if some of the hypotheses concerning pellagra are believed, but the diet was also deficient in calories, thiamin, riboflavin and nicotinic acid. Then it was that painful feet returned in another though less severe epidemic. It is interesting to note that both here and in a number of the working camps where the burning feet syndrome was again encountered, its return was by no means so severe. The same was observed about relapses. No correlation existed between the symptoms of this state and consumption of tobacco, and in general there was no evidence of any toxic cause. There seemed to be some racial influence, as the Ambonese and Manadonese in camps in Netherlands East Indies had few avitaminoses and hardly any trouble with their feet or eyes in spite of the insufficiency of the diet.

The Australians were severely attacked in 1942. One suggestion advanced to account for this was that they were usually heavier in their average weight and were accustomed to a high protein diet owing to the

liberal allowance of meat in their standard ration. It is possible that protein metabolism may also have played some part. Another point which may be important is that manifestations believed to be due to pellagra appeared later on but were not seen at the same time as painful feet. Treatment also sheds some light on the nature of the condition. It was naturally most effective in men whose symptoms had not been long established.

In an investigation carried out in 1942 in Changi, results were apparently obtained from nicamide, thiamin, rice polishings and yeast, but dosage was very restricted on account of the small quantity available. Injections of calcium were tried, but had no effect. Later, when grass extracts were produced in considerable quantity, and particularly when soya bean was available, the conditions seemed to subside. As a general routine in hospital, the use of rice polishings, marmite and extracts of towgay, providing riboflavin, seemed to be satisfactory. Extra food designed to improve the balance of the diet was effective if available, particularly when yeast was also given.

Early in 1943 in Burma at Thanbyuzayat, a troublesome outbreak occurred; the only supplements available were bananas and eggs, but these appeared to give satisfactory results. Treatment by vitamin *B*1 extract was unsuccessful. In camps in Netherlands East Indies it was found that one egg and one drachm of yeast daily would cure lesions of the lips and mouth and scrotal dermatitis, but would not affect painful feet. Doubling this supplement, however, was successful. It was suggested, therefore, that there might be a combination of lack of calories and first class protein with a lack of the *B*2 complex. Further experience with nicotinic acid was not encouraging. Infra-red radiation was tried at Changi with an extemporised apparatus; it seemed to give some relief of symptoms, but no controlled observations were made. An important factor in treatment was the wearing of properly fitting boots, provided these were available, and foot exercises were beneficial. Sedatives were sometimes necessary.

An observation of some importance was made by Coates in Burma. He was successful in relieving the symptoms of a patient with severe pain in the feet by dividing the superficial peroneal and tibial nerves. At the operation a distinct swelling of the nerves was noticed, but no microscopic examination was possible. He supports the view that the vascular changes were at least associated with an abnormal state of the peripheral nervous system. This fits in with the observation that neurological disturbances such as spastic paraplegia may occur as direct sequels of burning painful feet.

Captain D. J. Brennan, in his observations of severely affected men in Manchuria, pointed out that the feet looked very different at night; in the daytime their colour was a dull slaty grey and the skin looked thick and smooth and was dry, but at night the feet were swollen and, while there was no pitting on pressure, the bright red skin looked tense and shiny. The veins were dilated and stood out prominently as far as the knee or

even further. Some degree of spasm was present in the muscles of the leg. At night also hypersensitivity of the skin was more evident to touch and pain, but the perception of heat and cold was not altered. The arteries could not be palpated at night owing to intense pain. He also observed that ankle jerks were sometimes difficult to elicit on account of the muscle spasm. No hypertension was found. Some of these findings are significant from the point of view of involvement of the nervous system. Brennan thought that the vasomotor changes were secondary to a disturbance of the autonomic nervous system and also felt that cold produced aggravation of the symptoms.

It is interesting, too, that these severely affected men were Allied soldiers who had been under bad dietetic conditions for some time before coming to the camp at Mukden. Patients with a long history, as some of these had, could not be relieved easily, and in any case no real facilities for treatment were available in Manchuria. It seems possible that structural damage occurred in some of these men, who had symptoms still present even after three years. This contrasts sharply with the experience in Changi where, with the better conditions and facilities, the outlook was very good, as all the patients improved under care and recovered ultimately without any residual symptoms.

I. SPASTIC PARAPLEGIA

During the months in which the men in Changi experienced their worst epidemic of the burning feet syndrome, a small group of cases of spastic weakness of the lower limbs was seen. It has been shown that increased reflexes were not infrequently observed in the subjects of painful feet, even occasionally with ankle clonus and extensor plantar reflex.

Consideration of the times at which the different clinical syndromes appeared suggests too the possibility of a relation between this malady of the nervous system and lesions of the skin and mucous membrane. Between June and October 1942 some 40 patients with spastic paraplegia were seen in the Changi area; only 6 of these were Australians. The mildest cases occurred at the end of the period, and after this the disease disappeared and was not seen again. W. A. Bye reviewed 18 patients in Changi hospital. There was no evidence that these men had suffered any severer degree of malnutrition than others, or that a greater proportion of them had had dysentery or diarrhoea. The death of three patients from dysentery is probably irrelevant.

The onset was usually sudden. Within several days weakness of the legs appeared and became severe. Movements were noticeably clumsy. Both legs were usually affected, though not always equally, and the arms were often involved to a lesser extent. Occasionally the trunk muscles were involved also, and the patient was left temporarily almost helpless.

The first symptoms were subjective, but objective signs, though at first misleadingly absent or inconspicuous, soon appeared. Sometimes a slower onset made the diagnosis of organic disease difficult in the early stages. All degrees of paresis were found, but there was no wasting. All the usual

signs of pyramidal tract involvement appeared; flexor spasm was common. Sphincters were involved only in the severely affected patients, who died. Sensory changes could not be demonstrated other than those usually found in association with beriberi. A high temperature was found in men severely affected, a sign also observed in occasional cases of other nervous disease believed to be due to vitamin deficiency. In such men the mental state was seriously disturbed; this was not usual, though some impairment of memory and concentration was noted in a few. Loss of visual acuity was found in the severe cases; it was difficult to test the visual fields of these men, but no fundal changes or scotomata were apparent. It was possible that any changes in the visual neural paths were in the optic tracts, radiation or cortex.

Dysarthria was a well marked symptom in some. Facial weakness was seen in a very few. No skin lesions or other conditions suggesting pellagra were observed. Lumbar puncture and examination of the blood did not reveal any abnormality.

These patients were treated on the assumption of a deficiency state, with dietary supplements. Though some of them could be given special food only during their acute state and thereafter had the average diet of the camp for that period only, they made satisfactory recoveries, without relapse or recurrence.

Some degree of recovery began as a rule within five or six weeks and after four or five months in hospital, or less in less severe affections, the patients were usually well. Even though function was satisfactorily restored, some exaggeration of the reflexes often remained. Some disability often remained in the form of stiffness or weakness, but not sufficient to prevent carrying out of light duty. Even two years afterwards, a patient capable of doing light work has been found to have hyperactive deep reflexes and ankle clonus.

In general, power in the arms was recovered, speech if previously affected was normal, and some changes persisted in the lower limbs. Nothing suggestive of a pellagrous state was found in these men at a later date; they had no lesions of the skin or mouth, no chronic diarrhoea and no mental changes. In a few, permanent disability remained, not severe enough to prevent standing or walking, but enough to hinder complete freedom.

The cause of this syndrome was believed to be deficiency of protein and of the vitamin *B* complex in the diet. It is hard to see why its incidence was so limited and why no more cases occurred. The existence of some degree of disturbance of pyramidal tract function in the painful feet syndrome suggests a sequential relation, but on the other hand there are undoubted affinities with some of the experimental and other lesions attributed to pellagra. We must of course admit the logical danger of assuming that the use of the name of a disease such as "pellagra" explains its cause or describes its pathology. It may be remarked that numbers of men who died in the working camps of the Burma-Thailand railway were diagnosed as having pellagra by experienced medical officers. If this

paralytic disease was a form of pellagra, it might have been expected to appear among these men. Post-mortem information is meagre about this form of spastic paraplegia, as examination was limited to macroscopic scrutiny. Lesions were observed in the white matter of the brain, especially in the posterior and superior part of the cerebral hemispheres, extending back into the occipital poles. There were circumscribed, symmetrical rounded areas of a grey translucent appearance. They were thought to be due to demyelinisation. It was fortunate that the changes in the nervous system were not irreversible in a greater number.

J. LESIONS OF THE SKIN

The most obvious and destructive of all lesions beginning in the skin was the "tropical ulcer". This is described fully in other sections. It is mentioned here because it is beyond question that these lesions would not have attained the size and extent they did in the Japanese prison camps had the nutrition of the men been adequate. There is no doubt that dietary deficiencies played a considerable part in undermining resistance to infection and in hindering normal healing. That there was often a deficiency of vitamin *C* in the diet is beyond question. Captain W. Aitken noticed petechiae particularly in the skin of the arms of men on Hainan Island whose diet was deficient in vitamin *C*. Scurvy as a clinical syndrome was not recorded, but experience in the world during the 1939-1945 period has abundantly shown that clinical syndromes, due to deficiency states, even appearing in epidemic forms, frequently did not conform to the patterns regarded as classical. Probably in the worst working camps, such as some of those in Burma and Thailand, almost every possible permutation and combination of dietary deficiencies existed at one time or another, together with infections against which few measures could be taken. It may well be that a lack of vitamin *C* and of elements of the vitamin *B* complex, whose metabolic influence is exerted in part on vascular tissue, was an important factor in perpetuating ulcers. Apart from the septic ulcers, the most serious lesion of the skin was a generalised dermatitis. This has been mentioned in the section on dermatology, where its occurrence is described under conditions of satisfactory nutrition. In the present instance the additional factor of nutrition is undoubtedly important, but this does not preclude the possibility of toxic or allergic causes also operating. Whether a hypothetical toxin is of intrinsic origin or not, its potentiality for harm may easily be greater in the presence of disturbed cellular metabolism. Scrotal dermatitis has been regarded as a local specific manifestation of exfoliative dermatitis, and the connection of this lesion with avitaminosis is reasonably certain. The peculiar susceptibility of the skin and mucous membranes in persons lacking important vitamins of the *B* complex is well known. Therefore, without our being committed to a diagnosis of pellagra, meaning by this the end states described under that name, it is admissible to refer to "pellagroid" conditions of the skin.

Such rashes, when affecting exposed areas of skin, were symmetrical and photosensitive, and were common in certain areas and at certain

periods. They were first seen in Changi in 1942. In men seriously malnourished in the worst camps, this type of rash was sometimes associated with loss of muscular power and some mental deterioration. Chronic diarrhoea was very common owing to the prevalence of bacillary and amoebic dysentery; it would be impossible to ascribe it to pellagra or to any single cause in many of the men so affected. Post-mortem examination on men who had had such manifestations often showed the whole intestine to be thin and translucent with a smooth atrophic appearance of the mucosa. Coates and other surgeons commented on this state of the bowel as seen in abdominal operations. Further reference will be made to this later.

The pellagroid rashes resembled sunburn in the early stages, and were delimited at the edges, though not always with absolute sharpness. Pigmentation and desquamation were soon observed. It is curious that the back of the neck was not always affected, though this area was usually unprotected. Pigmentary anomalies were also observed on exposed parts, apart from this photosensitive dermatitis. Areas of deepened pigment formed by aggregation, leaving others depigmented.

Associated with these skin lesions were usually the familiar conditions of the muco-cutaneous junctions and the affections of the lips, mouth and tongue already described. These are, in part at least, ascribed to a defect of riboflavin, but are often clinically recognised as part of the pellagrous syndrome. Consequently, some medical officers referred in their reports to pellagra, where others merely described the appearances seen or related them to a deficiency of the *B*2 complex in general. Among groups of men with rashes aggravated by the sun, scrotal dermatitis, oedema of the feet, stomatitis, cheilitis and glossitis were also frequently observed, and occasionally too, some degree of nerve deafness.

In 1945, when the state of nutrition in Changi was deteriorating rapidly, parallel with a steadily worsening dietary, pellagrous dermatitis increased greatly in amount. After working in the sun, men would have painful inflammation of the skin over the outer arms, the backs of the forearms and hands, the backs of the knees and the dorsa of the feet. Occasionally the face suffered also, but the neck, shoulders, back and chest were less often affected. At this time, lesions of the mouth were not usual, one of those curious exceptions to the experiences elsewhere at other times, that sheds some light on the condition. It was noted too that ascites was then occurring more frequently, probably owing to shortage of protein in the diet; tapping was more often necessary to relieve the symptoms.

One feature of the diet which is of probable importance then is that maize was included in the diet from the 20th March 1945 to the 21st May 1945, and then withdrawn. Sun rashes became more common at the latter part of this period, and a little later when many such rashes were being seen, maize was re-issued. The connection between maize and pellagra has been the subject of much argument for years. Reference will be made later to the possible effect of black beans in the diet; these

matters are of interest, as suggesting the plausibility of the hypothesis that one effect of certain vitamins may be detoxication.

Special interest was given to the observation of lesions of the skin in Changi when a new symptom-complex appeared in the area. The word "new" is used in the sense that these manifestations had not previously appeared as an entity there. The clinical features of the syndrome were inflammatory lesions of lips, mouth and tongue, dermatitis, and changes in the blood. The most striking feature of the blood disturbance was neutropenia, which will be described separately later. These new manifestations caused the skin lesions to be described with special care, and the following details taken from a report by Lieut-Colonel W. A. Bye, set out the skin conditions observed in this outbreak.

The lesions varied in severity from mild erythema to generalised exfoliative dermatitis. Only the exposed parts of the body were affected, and these areas were symmetrical. The earliest signs were either pin-point papules, or small vesicles on the shoulders or abdominal wall, with a red swollen base. Rupture of the vesicles left a raw weeping surface. Less often scarlatiniform, or even purpuric rashes, were seen. Itching or burning or tingling was complained of, and sometimes the onset from this early stage was very rapid.

Desquamation was usual, and occasionally was extensive in amount and degree, and between the peeling areas there might be eczematised patches. In over 25 men, severe exfoliation was seen; large pieces of skin were sometimes shed, cracks and fissures often being left. Exfoliation sometimes recurred repeatedly on the affected areas, which in the interim were pigmented, though soft and tender. After 3 or 4 months leucodermic patches appeared in a number of men, either small or large, on the exposed parts or between the fingers. Fever was common during the period of exfoliation. Bye noted in a few men an appearance on the palms resembling an early stage of pink disease. Though similar photosensitive rashes had been seen in Changi in 1942 with clear demarcation of the affected areas, this feature was now lacking.

Discussion of the aetiology of this condition is better left until the blood changes have been described.

K. CHANGES IN THE BLOOD

Although there was no doubt that many men suffered from anaemia, full investigation was usually impossible. There is no record, for instance, of any series of anaemia of macrocytic type as might perhaps be expected, but the existence of this and of other types of blood disturbances cannot be excluded.

One variety of important change in the blood and in the bone marrow was investigated in Changi in March to May 1944 when what was known as the "new" syndrome appeared. One of the features of this was a form of myelophthisis in which the white blood cells were involved. The appearance of some of the lesions of mucous membranes of the mouth and throat suggested the possibility of a neutropenia, and blood counts, both total

and differential, were then carried out by Major Maynard, A.A.M.C., on all patients whose condition was serious. Three men died and in each instance the total white cell count was reduced, and particularly that of the neutrophile cells. Counts in these fatal cases were sometimes as low as 2 per cent neutrophile cells, the lymphocytes rising to 80 or 90 per cent. In a few instances bone marrow was obtained by sternal puncture. Observation of other patients who recovered showed that a severe neutropenia sometimes occurred, but was usually transitory, and after an interval varying from one to three weeks, total and differential white cell counts became normal. As is usually the case in neutropenic states, the white cell count in itself did not give a true indication of the prognosis. It may be noted, however, that in no instance was a total absence of granular cells observed. The lower white cell counts were associated with the more severe lesions in the mouth and throat, but even severer exfoliation of the skin did not produce any substantial lesion of the blood. Anaemia of itself was not a feature of these conditions, though of course it was seen in connection with relapsing malaria and other infections. There was no evidence that these blood changes were due to drugs. Sulphapyridine was used in the treatment of intercurrent dysentery and sometimes for lesions in the throat itself. Total doses did not exceed 5 to 15 grammes and observations of the blood counts did not suggest any connection between the two. Recent experimental work sharpens our interest in these syndromes, as skin pigmentation has been described in deficiency states, and nutritional leucopenia has been successfully treated with folic acid.

Post-mortem examination in the fatal cases showed findings consistent with deficiency disease of a pellagroid type and of severe neutropenia, with its usual septic sequels. The possible causal factors of this syndrome were carefully considered in a report on the subject, which pointed out that during the previous two years the diet supplied to the men was of a very low Asiatic type. It was curious that during the earlier periods symptoms of the skin and mucous membranes such as are often associated with pellagra, were frequently observed. It was realised that in accordance with the more recent views in the literature, such signs were possibly due to deficiency in riboflavin, but all that could be said definitely was that the signs and symptoms were possibly due to a lack of this and other components of the vitamin *B* complex. In February and March 1944 the rice ration was reduced in amount and for the first time maize was added to the diet. The average issues per man per day varied from about 2 ounces to 4 to 5 ounces. Whether there was any association between the maize and the onset of pellagroid symptoms cannot be stated. Major Burgess, R.A.M.C., who was an expert on nutrition, prepared analytical tables of the diet supplied to the troops throughout the whole period in Changi. These tables showed that in April and May 1944 a slight fall in the caloric value occurred, but even more significant was a substantial fall in the amount of nicotinic acid in the diet. This began in January 1944, and in May remained unaltered. The riboflavin content of the

diet fell also progressively through the year, though there was no sudden drop such as took place in the nicotinic acid. Dietary supplements at this period were also very scarce, rice polishings were unavailable, towgay had not been issued for some time and fresh vegetables and fruit and eggs were very scarce. In February 1944, black beans were added to the ration in average daily quantities of 1.5 to 2.3 ounces per man. Both in Changi and Kranji, it was thought that some relapse or exacerbation of skin conditions occurred each time these beans were added to the diet. Some men appeared to be upset by them, but no definite evidence of any toxic effect was forthcoming. Skin tests were made with an extract of the bean, without result. It was thought more prudent to omit them from the diet, though without definite proof of the necessity. The question was also raised of the possible importance of coincident infections of the throat, but throat swabbings did not support this suggestion. It seemed rather as if a defect of blood formation or maturation preceded the onset of secondary infections. It was therefore concluded that this was a true deficiency disease. Men affected were treated with marmite, limited amounts of rice polishings, or extract of towgay and soya bean. A very limited supply of nicamide was held, but very little could be spared for treatment. In the limited experience possible, results did not seem to be encouraging. Grass extract was used in doses of a pint daily for patients who could tolerate it. The grass used was blue couch or paspalum or lalang, extracted by boiling and concentrated. Pain on eating and swallowing was considerable in many instances and frequent feedings of soft diet were given.

It is of interest to trace the further developments of this deficiency state. After May 1944 the numbers fell rapidly. Lesions of the lips and mouth became less severe, no ulceration was seen, exfoliation of the skin did not recur and no neutropenia was found. This improved state of affairs was observed not only in the hospital area, but also in the various units. At this time many patients were transferred from Changi to Kranji and the same improvement occurred there also. It was noticed, however, that men who had recovered from exfoliative dermatitis had certain sequels. They lost considerable weight, were very easily fatigued and had chronic skin changes. Non-pigmented patches could be seen on the skin of the face, chest, shoulders and back and limbs. These were very subject to sunburn. Between the pale patches, the skin was browner than usual, and a number of men showed also a chronic purplish pigmentation on the backs of the hands. As these men could not tolerate exposure to the sun, they were regarded as suffering from a chronic mild form of pellagra.

At this time also an increase in manifestations previously attributed to vitamin *B*2 deficiency began to recur in the area. A certain number of men complained of abdominal discomfort and mild diarrhoea, but it was by no means sure that this was due to deficiency. No neurological abnormalities were observed. It seems warrantable to conclude that by August 1944 pellagra with its associated lesions of *B*2 deficiency was endemic in the Singapore camps.

L. EYE DISTURBANCES

(*a*) *Corneal Degeneration*

Early in June 1942, a number of men began to complain of what appeared to be a form of superficial keratitis. This was also described as "granular cornea", for keratitis was not a completely accurate description. The symptoms were sometimes slight; conjunctivitis and blepharitis were occasionally seen, but little or no discomfort was usually felt. There was sometimes a slight feeling of grittiness, with some sensitivity to light and occasionally lachrymation with a little discharge. Affection of vision was usually slight. Faint opacities and irregularities were seen on the cornea with slight injection around it, and a drop of fluorescein produced fine corneal staining. This staining was diffuse, but had a punctate appearance, discernible with a *loupe* and good illumination, and was usually more evident over the lower and more exposed part of the conjunctiva. Sometimes a line of fine spots could be seen crossing the centre with minute branches. In more advanced conditions, the punctate areas coalesced, causing loss of epithelium over a wide area. The lesions were superficial and Bowman's membrane was seldom involved. The corneal reflex was usually present, and there was little interference with sensation. The progressive changes in the corneal epithelium can be summarised as steaminess of the cornea, granulation and superficial ulceration.

In August and September 1942 it was noticed that the men in hospital who were having marmite for the treatment of skin conditions showed improvement of these corneal lesions. Marmite in this respect was more potent than vegemite. Rice polishings seemed to produce little result. These observations and consideration of the prevalent conditions pointed to the existence of another deficiency disease.

During November and December, the incidence fell, owing probably to the availability of some dietary supplements, some of which came from Red Cross food. These supplies ceased in December, and in March 1943, there was again an increase in corneal degeneration. It may be also relevant that in January 1943, prophylactic rice polishings could not be obtained. This lesion, as Major Claffy pointed out, was not inflammatory in nature, though the changes in the cornea differed from those described in the literature as a result of lack of riboflavin. He suggested that the cause might have been a combined deficiency of vitamins *A* and *B*2. In support of this, it was noted that the incidence fell after palm oil was added to the diet, which was rich in vitamin *A*. Varying degrees of night blindness were occasionally seen among the prisoners of war, but this was not a feature at this time, and the other lesions described such as softening of the cornea and Bitot's spots were not seen. The evidence of an *A* deficiency was presumptive only.

Local treatment had very little effect and usually consisted in the use of oily drops. The condition seemed to have a natural tendency towards recovery. One of the most valuable local methods of treatment was to keep the eye covered; if this was done, the cornea soon became smooth

and fluorescein staining disappeared; but if prematurely uncovered, the eye tended to relapse. Response was obtained as a rule within two to ten weeks, but sometimes recovery was further delayed.

In the latter half of 1942, it was noticed that the degree of visual impairment apparent in these men was greater than could be accounted for by the corneal lesion. Further, while the granular state of the cornea as a rule resolved with little or no residual scarring, the eyesight did not always improve.

Major R. G. Orr found that even severer corneal lesions cleared well without any permanent defect when extract of lalang grass was given, but from the evidence it is hard to determine the effect of separate dietetic supplements. After the first epidemic outbreak, corneal degeneration as a single deficiency symptom gave relatively little trouble, but was seen from time to time to some extent under conditions of inadequate nutrition. Even when troops were returned from the prison camps to Australia a certain number of men had a loss of lustre in the epithelium of the cornea and a few spots due to superficial nebulae. This deficiency syndrome, like most of the others, kept up some smouldering activity. As the number of men with ocular complaints increased, it became evident that a more serious type of affection of the eye was becoming prevalent. This form of deficiency disease, known variously as retrobulbar neuritis and deficiency amblyopia, continued to be of importance throughout the whole period, although the numbers waxed and waned gradually from time to time.

(*b*) *Deficiency Amblyopia*

The name retrobulbar neuritis has also been used for this, but as it does not resemble the usual forms of this complaint and has a different pathology, it is perhaps better to use a more non-committal term.

In the Changi areas, the numbers showing interference with vision, increased rapidly at the end of the year, the peak occurring in January 1943. It is possible that a growing consciousness of the significance of any dimness of vision caused a large number of men to report early, especially as the importance of early treatment was stressed.

Affected men noticed blurring of vision; this might be in one or both eyes, but always began in one first and involved the other later, an important point in the matter of early treatment. The blurring affected particularly near vision so far as subjective sensations were concerned. In reading, for example, words would drop out, and if the affected area was central or near-central, the functional loss was all the greater. Occasionally a kaleidoscopic type of image was seen owing to the movements of the eye in an effort to fix a central vision.

Both Major Claffy and Major Orr saw large numbers of men with this eye condition, collected details of their findings with great care, and kept records of the results of treatment. There was some difference of opinion at first among those carrying out treatment as to which dietary supplements were most successful and whether it was essential to admit all patients

to hospital for early thorough treatment. A difficulty arose in treating all patients as in-patients on account of the shortage of hospital beds.

Much was, and still is, obscure about this disease, but though differences of opinion were held on certain aspects, general agreement was reached about its most important features. Major Claffy issued a number of reports on the subject, and collected his experiences into a report covering the whole period of 1942-1945. Major Orr and Captain Woodruff, in the Selarang area, examined the various factors which might be considered the bases of treatment, and tried to ascertain on statistical grounds which were the most effective methods to pursue.

In the hospitals in Changi and Kranji, 2,000 patients with this disability were seen of Australian, British, American and Dutch nationalities. Soon after the appearance of corneal degeneration, detailed examination of the eyes of some patients showed the presence of scotomata.

By October 1942, amblyopia reached epidemic proportions, which were maintained until July 1943. At one time, out of a total of 830 patients in hospital, 500 were being treated for amblyopia. After this the incidence decreased, owing partly to better diet and partly to the moving of some of the force from Changi. Part of the Changi Hospital was moved to Kranji in May 1944, where conditions were more primitive. Here, after a latent period, relapses occurred and fresh cases appeared, but the produce of a communal garden of some 28 acres and the addition of the right kind of greens and of soya bean induced remissions. About this time the total calories of the diet provided by the Japanese were reduced and although bodily resistance declined as a result, the diet was better balanced and for a time no fresh cases occurred. Later again, new cases once more appeared and among the patients was a certain proportion of men who had partial ophthalmoplegia. Occasional instances of this condition had already been reported by medical officers in other areas, but very few had occurred until this group appeared. These pareses were believed to be due to thiamin deficiency. Patients with this form of amblyopia showed varying degrees of impairment of vision. If this was 6/18 or less, searching movements in the eye could be noted in an attempt to obtain fixation. The pupils usually reacted normally and examination of the fundus of the eye rarely showed change. Occasionally slight blurring of the discs, indicating a mild papillitis, was recorded. In this series 1.5 per cent had retinal haemorrhages, usually small, but occasionally of moderate size, although there was no evidence of fragility of the other blood vessels. Bitemporal pallor has been sometimes described, too, but this is a sign to which importance cannot always be attached. There is no doubt that severe loss of sight could occur with no substantial change in the eye grounds. Since the return of these prisoners of war, it has been again demonstrated by the observance of controls that pale discs and the presence of deep cupping may exist without any interference of vision. On the other hand, large scotomata may exist without any such retinal findings. Nystagmus was only rarely seen. The one characteristic lesion was the scotoma. Within the limits of its area, loss of vision was para-

central or central or caecocentral or annular. The scotoma was for white and sometimes for colours; for example, for red in the early stages, but this was not characteristic. A pathologist noted this in himself when he could not distinguish the red stained tubercle bacilli on a microscopic slide.

Peripheral vision was usually not affected, but sometimes some contraction could be observed. For practical purposes, it appears to be true that complete blindness has not occurred. Accompanying symptoms were slight only. Loss of clarity of vision was sometimes accompanied by a feeling of strain, and photophobia was an occasional complaint. Work in a strong light seemed to produce a sensation of aching behind the eyes in some men. Vision was better in dull light, especially in the evening. The loss of visual acuity might be confined to one eye or might affect both.

Aetiology. Apart from general causes, such as lowered nutrition from insufficient or unbalanced rations, intercurrent disease and excessive muscular work, other factors considered were a specific vitamin or other dietary defect or an endogenous toxin, which might be produced by the resultant disturbed metabolism. There appeared to be a specific damaging effect on the neural elements of the retina or on the axis cylinders of the nerve bundles. In any case, the lesion was a peripheral one, and the absence of half or quarter field defects indicated that the part affected was below the chiasma. Experiences in treatment has shown that some of the milder types of amblyopia would become stabilised without specific treatment. This was probably due to a restoration of the vitamin requirements through lessened strain on the general metabolism, or possibly to some degree of bio-synthesis. Such spontaneous recovery of course could take place only when the changes in the nervous structures were not irreversible. Other forms of avitaminosis were observed in patients with amblyopia, but these varied in the different periods and shed a little light on aetiology. In December 1942, for example, 75 per cent to 80 per cent of the men with painful feet, stomatitis or scrotal dermatitis, also had amblyopia, but a year later the percentages were only from 2 to 15.

Amblyopia was common also in the poorly fed men of the worst working camps, but here co-existence of other deficiency states was much less common than in Changi in 1942. Major Moon in the 2/2nd Australian Casualty Clearing Station in Java, divided the men into several groups, each receiving one special variety of food in addition to the usual ration. The supplements included liver, eggs, meat, beans and fruit. He found that no new cases of affected sight occurred in the groups receiving extra animal protein; in this regard tinned meat appeared of definite value in prevention. A large amount of carbohydrate had a bad influence and appeared to accelerate the appearance of amblyopia.

In a discussion on this subject by a group of Allied medical officers held in August 1942, after the epidemic had begun, the following features were noticed. Australians (usually heavy meat eaters) were affected early, burning feet preceded the outbreak of amblyopia, no pellagroid signs were noted at the time; other races contracted pellagra without having ambly-

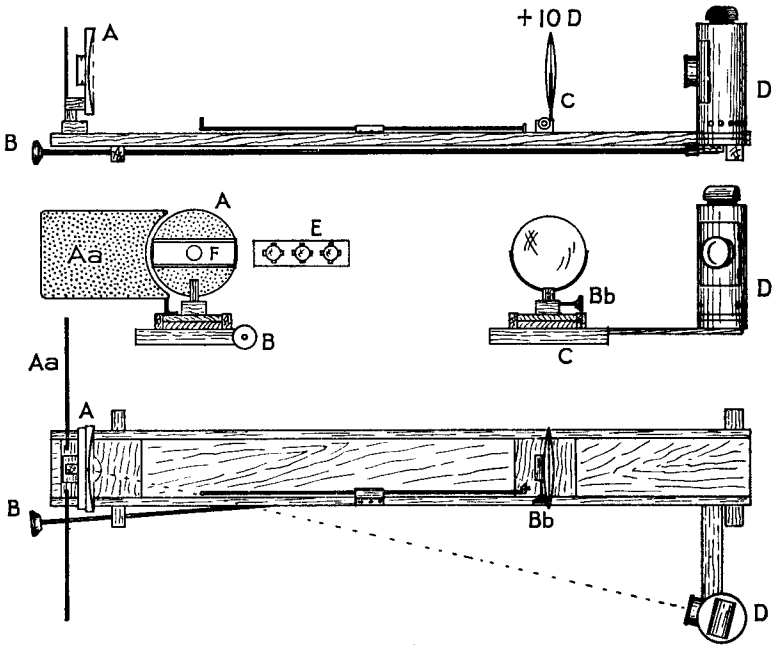
opia, and no connection was found between the existence of lesions of the skin and of the eye.

The results of treatment gave some information on the aetiology. Major Claffy reported good results in a series of one thousand cases, with of course the proviso the treatment was not so effective once the lesions were firmly established. He considered that rice polishings alone had no value and that marmite, together with as satisfactory a diet as could be contrived, gave good results. Major Orr and Captain Woodruff analysed another series treated in the Selarang area. No evidence could be found to implicate tobacco of any other known potentially toxic substance, and experiments on the possible effect of replacing various items deficient in the diet were not quite conclusive owing to the limited numbers, but it appeared from this that thiamin and nicotinic acid alone were ineffective, although the amounts of the pure substances available were very small. The results with marmite, rice polishings and yeast, together were better than with those of marmite alone. The varied degrees of affection of the different men and the slow rate of recovery in some, made assessment of results difficult. Supplies of marmite were difficult to maintain; but when this was unavailable, the use of soya beans in the form of "tempe" and other garden produce such as kang kong and spinach was encouraging. Soya bean and kang kong appeared to be the most effective substances. Long term experience over the three years of captivity showed that all patients treated early did well and most of these had very little, if any, permanent impairment of vision. Where atrophic changes had occurred, even without demonstrable pallor of the retina, the conditions usually remained almost stationary. Unfortunately, it was possible to treat men from some of the working camps only when their condition was already far advanced; an example of such was a series admitted from Pulau Dama. A certain degree of improvement took place up to 18 months or 2 years, but after that nothing more could be expected. There was evidence in favour of the view that avoidance of heavy muscular exertion and of an unbalanced ration containing too much rice, were measures of great importance in the treatment of this condition. Some degree of optimism was justified even in severe progressive cases as the atrophic changes might stop at any stage. In fact, it was believed that treatment produced some degree of improvement in practically every instance. Analysis of 844 cases after an average of 2 months' treatment, showed that over 90 per cent of the men had 6/18 vision or better in each eye, and 50 per cent had 6/9 or better in each eye. It was thought that 7.5 per cent were left with a marked residual impairment of vision. The degree of permanent disability depended not only on the extent of the damage, but on the position of the scotomata.

In some of the long continued cases, there appeared to be a chronic bilateral form of this disease. In this, peripheral vision was usually intact and it was thought that a loss of central vision was due to involvement of the papillo-macular bundle. Recurrences and relapses occurred in

numbers of men; these were believed to be due to unfavourable changes in diet or undue exertion.

Major A. R. Hazelton had opportunities in base areas in Thailand for studying men with nutritional amblyopia who had been subjected to excessive fatigue as well as partial starvation. When these men came under treatment at Nakom Paton in 1944 hospital dietary supplements were more readily obtained, and some Red Cross supplies were available. Leucomata following corneal ulceration were common, and active corneal lesions were frequent. Photophobia was often observed, particularly in men suffering from nutritional amblyopia. As sufficient dark spectacles could not be obtained, the total number available was ingeniously increased by cutting lenses in half and fitting them in extemporised frames made from tin cans. Hazelton's clinic also used extemporised apparatus for



A - Concave mirror, focal length 75cm. approx., moving in a lateral and vertical direction, with holders to take slide (E).
Aa - Black shade to stop light from oil lamp (D), shining in right eye.
B - Knob for adjusting end of machine. Constructed from Rolls razor, and moves approx. 1½ ins. on either side of centre.
C - Adjustable lens holder, operated by turning knob (Bb). Vertical movement.
D - Lamp constructed from tin. Burning coconut oil. Hinged door on front.
E - Slides with lens, from +1½D to +3D and from −1D to −2D, to fit in runners (F) at back of mirror (A).

Diagram of ophthalmoscope constructed in Nakom Paton by Major A. R. Hazelton.

testing and assessing visual function in the amblyopic patients. Promising results were obtained in cases of short duration by the use of a special diet containing 10 eggs per day for 30 days. Tests of visual acuity, fusion, and fields of colour vision showed distinct improvement in all cases in this series, and one patient was considered cured.

In summing up the results of treatment, it would seem fair to say that no true specific was really in the hands of the medical officers. The removal of a man from conditions of laborious work, and unbalanced or improper diet in which a number of substances were deficient, such as protein, calcium, phosphorus, vitamin *A* and the various components of vitamin *B*, even without special treatment, probably allowed him in many instances to swing the balance towards recovery.

(*c*) *Night Blindness*

Experience in men in the field showed that night blindness could not be accepted as an organic disability unless demonstrable by tests. In certain circumstances it is not surprising that protective symptoms of a functional nature arose, but these were not of common occurrence. When undoubted malnutrition and a deficiency of vitamin *A* were present, night blindness was occasionally recognised. Amongst soldiers of the 8th Division, it is impossible to state how common it was, but decreased visual acuity at night was observed in some in association with and following attacks of conjunctivitis. Soreness and watering of the eyes, usually with little purulent discharge, were features of these attacks. As the diet improved these symptoms and the lowering of visual acuity by night also improved.

Examination of the diets in the prison camps shows that lack of vitamin *A* was very common, the daily figure seldom reaching 1,200 international units. In Nakom Paton in March 1944, the total vitamin *A* available was under 1,100 international units; in January 1945 it was 1,888 international units, but on August 1st-10th, when the end of the war was imminent, it rose to 8,470 international units, a striking increase after the previous figures, which were always below standard requirements. Special diets for the sick provided more, through the efforts of hospital staffs, so that a man with acute dysentery, for example, would receive 6,000 international units vitamin *A*, dropping back to 1,560 in convalescence. The higher figures were obtained from locally grown kang kong, which contained 100,000 international units per 100 grammes. In the Nakom Paton area, night blindness was apparently very uncommon and xerophthalmia was not seen.

Further special reference to this subject will be made in the volume describing medical work in the Royal Australian Air Force, which like all air forces, was particularly interested in the visual capacity of air crews.

OTHER FORMS OF DEFICIENCY STATES

Isolated symptoms of various kinds appeared among malnourished prisoners of war which are hard to place because their cause was obscure.

Nocturnal diuresis was one of these, and occurred frequently. Due apparently to an effect of poor nutrition on renal function, it was a manifestation of a partial failure of the kidney to concentrate salt constituents. It may have had a vasomotor basis, and has been attributed variously to lack of riboflavin, vitamin *A* and protein, but its cause was unknown.

Other single symptoms arising in malnourished persons are probably better considered as part of the total effect of deprivation on the body.

Sprue is worth a passing notice. Sprue of the "tropical" variety was seen from time to time among troops on tropical service. The usual features were noticed, and full investigations were carried out in base hospitals in Australia on a few soldiers and airmen found to be suffering from the disease. One soldier had served two years in the Middle East and six months in New Guinea. Others had served for varying periods in the islands. Within a short period three soldiers were admitted to an A.M.F. hospital in Queensland, but this was probably coincidental, as cases occurred sporadically only in small numbers. A member of the nursing services was found to have sprue while in Colombo. The response was a favourable one, such as is usually characteristic of sprue of the "tropical" type, and intestinal and haematological disorders resolved under dietetic and replacement therapy.

Starvation

Finally it is well to draw attention to the importance of adequacy and balance of the major nutritive elements of a diet. When considering the extraordinary epidemic waves of distinct clinical syndromes which swept over the more unfortunate communities of prisoners of war, it is necessary to realise that they were not suffering from a single deficiency. At any given time a particular symptom pattern was prominent or predominant, but as such patterns appeared and disappeared the steady effects of general malnutrition were slowing and distorting the working of the metabolic machine. Many of the changes produced were persistent, some were irreversible, some made the weakened bodies more vulnerable to disease, and often to fatal disease. In a given physical state seen in grossly undernourished persons, who can say which changes are due to deficiencies of specific foodstuffs, or specific vitamins, or their imbalance, or which are due to sheer starvation? Here we cannot enter into the physiology of starvation, but must remember the importance of absorption of a sufficiency of food. Attention has been drawn to the conspicuous thinning of the walls of the alimentary tract, observed both in the living and the dead. This and other signs of abnormal response of tissues to trauma of all kinds are evidenced in the destructive "tropical" ulcers, beyond all civil experience. Difficulties in absorption were obvious in some of the emaciated patients liberated in time to have their lives saved, and the greatest care in selection of diets and in feeding was necessary to avoid undue strain on a fragile mechanism.

It was recognised in some of the prison camps that men were suffering from starvation, a deprivation of sufficient food to sustain life. Sudden

death was seen in beriberi; it was also seen in starvation. In Changi post-mortem examination revealed in these cases an atrophy of the heart, liver and spleen, and thinning to transparency of the intestines. Similar changes have been described in European prison camps where specific avitaminoses such as beriberi were not observed.

Finally it is most difficult to distinguish between disturbed mental states due to the environmental conditions, against which only the firmest of spirit could have prevailed, or those due to specific deficiencies, or to starvation or to all three.

One of the features of vitamin *C* deficiency has been described as mental depression and apathy. This was thought by medical officers to exist in some camps where ascorbic acid in the diet was insufficient for requirements. Without any special stress on this suggestion, it may be remarked that combatant officers were impressed by this state, in which there was vacuity of spirit rather than absence of mind, and an absorption in abstraction and misery. Lieut-Colonel H. R. Humphries, in charge of "H" Force in Thailand, concluded an interim report on the camp conditions as follows:

> "A frightening and peculiar symptom was manifest at one period, an intense, fixed but vacant kind of stare being present in the eyes of every man, and its despair could sometimes be detected in the countenances of some. I am certain in my own mind that in most cases this was purely physical, and a direct result of the low standard of diet."

CONCLUSIONS

The most striking features of malnutrition in Australian experience during the war have been the clear-cut serial clinical syndromes which occurred during long periods of inadequate nutrition in Japanese prison camps. Study of the literature shows that accurate descriptions of many of these states had been written a number of years before the war. Perhaps in the general medical world it was not realised that such conditions could arise again on so large a scale in a trained and well-equipped force. The tragic experiences of the 8th Division have shown what magnitude problems of malnutrition may assume, but have also indicated some possible adjustments which the human body may make. It is significant that while certain clinical pictures disappeared and did not appear again or appeared with lessened force, others persisted or appeared when comparable conditions arose. A certain relationship may be established between dietetic deficiencies and clinical phenomena, but there are so many variables that this cannot be pressed too far. The variables are such as troop movements, the amount and nature of work done, intercurrent disease, total caloric value of diets, balance or imbalance of the constituents of diets, and lastly the idiosyncracies of race and of individual. The diets available for most of these men were subject to serious deficiencies, particularly those of protein, calcium, and the vitamins *B, A* and *C*. The vitamin *B* complex and such components as riboflavin and nicotinic acid were probably more important than thiamin. The example of oedema quoted in the text shows the importance of multiple causes. For purposes of diagnosis and treat-

ment it was convenient to subdivide clinical states into categories. These were not really rigid, and overlapping was common. Thus it was possible to lay down certain criteria for the diagnosis of "cardiac beriberi" but it cannot be denied that the heart was implicated in the severer forms of beriberi.

Nutrition is in the post-war years one of the most, perhaps the most important single problem facing the world; the earnest studies of medical men faced with the frustrate task of dealing with grave nutritional disorders under conditions of stringent restriction help to lay emphasis on that problem.

APPENDIX 1

Japanese ration scale for British and Allied troops 1942.

Rice	500	grammes	(17.6 oz.)			
Salt	10	„	(0.352 oz.)			
Meat	50	„	(1.76 oz.)			
Milk	15	„	(0.52 oz.)			
Oil	10	„	(0.352 oz.)	Yielding 463	grammes	Carbohydrate
Tea	5	„	(0.176 oz.)	66	„	Protein
Flour	50	„	(1.76 oz.)	20	„	Fat
Vegetables	100	„	(3.52 oz.)	2296		Calories
Sugar	30	„	(1.05 oz.)			

Australian Standard Army Ration

Preserved meat	12 ozs.			
or Fresh Meat	16 ozs.			
Bread	16 ozs.			
Potatoes	12 ozs.			
Fresh Vegetables	12 ozs.			
Sugar	2 ozs.			
Bacon	2 ozs.	Yielding 488	grammes	Carbohydrates
Cheese	2 ozs.	175-185	„	Protein
Butter	2 ozs.	166-170	„	Fat
Jam	2 ozs.	4224		Calories
Condensed Milk	2 ozs.			
Salt	½ oz.			
Tea	½ oz.			
Coffee	⅓ oz.			

(On Jan. 1940 8 ozs. of orange or pineapple juice were added.)

APPENDIX 2

From an article by Cotter Harvey M.J.A. 1/6/46.

Year	CH grams	P grams	F grams	Calories	T/NFC	Riboflavin milligms	Nicotinic Acid milligms
1942							
Mar.	481	49	21	2,120	0.196	0.77	6.0
Oct.	536	86	51	3,030	0.48	2.1	21.3
1943							
Feb.	490	43	47	2,430	0.39	1.3	7.4
Aug.	548	86	49	3,054	0.53	2.6	17.5
1944							
Average	480	55	50	2,600	0.28	1.9	7.2
1945							
Mar.							
Workers	203	32	45	1,746	0.32	0.76	3.8
Non-workers	244	27	44	1,486	0.38	0.70	3.1
July							
Workers	261	26	52	1,623	0.36	0.68	3.2
Non-workers	227	25	51	1,482	0.39	0.65	2.8

APPENDIX 3

Analysis of dietary supplements (Captain E. K. Cruickshank, R.A.M.C.)

	C gm.%	P gm.%	F gm.%	Vit. B1 mgms. per 100 gm.	Riboflavin mgms. per 100 gm.	Nicotinic Acid mgms. per 100 gm.
Rice polishings	41	23	17	2500	0.25-0.5	20-40
Soya Bean	27	36	16	300	0.09	1.2
Green Grass (Phaseolus)	64	21	—	300-400	1.32	0.8
Ground Nut	22	20	48	800	0.94	5.9
*Green Leaf Veg.	3	2	tr.	50	0.50	0.40
Millet (Ragi)	72	12	2	200-300	0.30	0.8
Marmite	—	33	1	700	3-10	100

Nicamide (1.7 c.cm. ampoule) = 295 mg. Nicotinic acid.
Crystalline B1 = 1 mg. 333 I.U. (1000 microgrammes)
Requirements B1 — 1000 microgrammes daily.
R.F. — 2 mgm. daily.
Nicotinic acid — 20 mgm. daily.

* The extract used cannot be assayed: its Riboflavin content will depend on soil, fertiliser and method of extraction.

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CHAPTER 29

ENVIRONMENTAL CONDITIONS

HEAT

THE importance of the study of the effect of heat on men under training first became evident in Palestine in 1940. Previous efforts had been made to educate all training units in the correct procedure designed to prevent the pathological manifestations of extreme heat. Technical Instruction No. 11 of the Middle East series embodies the principles adopted in the A.I.F. in the Middle East, and is representative also of the views and practice of all services. (See appendix.)

Of the varieties mentioned in this, the least important was found to be the classical heat stroke or heat hyperpyrexia. Heat prostration on the other hand was by no means uncommon and was important, as the supply of water and of salt was involved.

Some of the combatant units of the I Australian Corps in training, started with the idea of attempting to accustom the men to a reduced water ration. The fallacy of this was pointed out and the danger of assuming that thirst, which is a physiological warning, could be disciplined past a certain point. The A.D.M.S. of the 6th Australian Division in the Western Desert advised against cutting down the water ration, although of course care was taken that the men did not consume unduly large amounts of water owing to the risk of loss of salt. In some instances salt was added in the correct proportion to supplies taken on manoeuvres or men were given either water or tea containing a quarter teaspoonful to the pint. In numbers of instances where on "khamsin" days, when hot wind was added to the discomfort of great sun heat, some men suffered from heat exhaustion. This occurred, for example, when a number of recently arrived men who had been taken to a staging camp where arrangements for food and water were not good. In June 1940 also, heat exhaustion and dehydration were seen in many men on brigade exercises owing to an insufficient allowance of water. Muscular cramp was occasionally seen and readily relieved by salt.

It is likely that some of the effects of water and salt depletion were not always recognised at the time. Fatigue and weakness, headache, apathy and dizziness, symptoms all produced by this cause, might be readily thought to be due to other causes. It is significant too that attacks of renal colic sometimes occurred in men newly arrived in the tropics, especially when exposed to exertion in severe heat. Sometimes a few red blood cells were found in the urine, but no other abnormalities, and if the symptoms were sufficient to cause vomiting, further dehydration took place, thus emphasising the renal symptoms. It has been mentioned elsewhere that the appearance of red cells in the urine in soldiers in the

Middle East was sometimes associated with oxaluria, but dehydration was a possible factor, which might easily have been overlooked.

When the campaign area shifted to the Pacific Islands, very different conditions were encountered in which the heat was frequently associated with a very high and constant humidity. This was further complicated by problems of clothing. In the Middle East the bitter cold of the desert nights in Cyrenaica, and the mountains of Greece and Syria demanded heavy clothing, but in the heat of summer, the comfort of shorts and shirts was usually permissible. In the island areas where malaria was hyperendemic, it was necessary that the body should be covered even though unpleasant side effects occurred. Not only was greater discomfort felt from the humid heat, but exhaustion occurred more easily, and troublesome skin reactions became much more common. These are described in the section on dermatology. The observations of Molnar and others are relevant here. They found in the Californian Desert that clothing reduced heat gain at air temperatures over 90°F., but not between 80° and 90°F. In general loss of heat by evaporation kept the body temperature constant despite heat gain from the environment.

In the Pacific Islands the need for salt became more urgent and salt tablets became a regular issue. Members of forward surgical teams in New Guinea, working under conditions of intense heat and humidity, found that they needed salt as much as combatant soldiers. G. Newman Morris remarked that in a surgical team: "A good batman is worth his weight in gold: he will see that smokes, tea and salt are ready". Many men in the Japanese prison camps were acutely aware of salt deprivation, accentuated by conditions of work and climate.

The actual figures relating to human requirements of salt are impressive, and useful data was published in 1943 by the War Office. In a brochure on salt, requirements in hot climates were given as 2 grammes per hour for a man at work and 0.5 when at rest; 12 grammes per day for sedentary occupations and 24 grammes for hard work. In a temperature of 95°F. and humidity 80-85 per cent 5.6 litres of sweat may be lost per day, and under conditions of great heat (100°-120°F.) and low humidity (25-30 per cent), as in a desert in the tropics, 4 to 8 litres. It would not be easy to supply the theoretically needed 1.5 to 2 gallons of water a day.

In febrile illnesses dehydration became an important factor in the tropical climates. This was more obvious where loss of blood had occurred, but it was equally important in conditions like severe malignant malaria, toxic dysentery and scrub typhus. It should be noted too that typhus is often associated with a fall in the chloride concentration of the blood.

Special precautions were taken in hospitals in tropical areas and fluid balance charts were found to be of the greatest importance in ensuring that dehydration was prevented, particularly in patients who were unable to cooperate well in the matter of taking fluids. The lack of initiative in drinking fluid commonly seen in sick, dehydrated patients was in part a sign of toxaemia and probably in part also a symptom of loss of salt. Orderlies, who were usually responsible for routine administration of

fluids, were taught to regard this as one of the most important of their duties, particularly in diseases like dysentery, which caused considerable fluid loss. Loss of salt may of course be proved by a simple test of the urine.

In parts of the Australian continent the heat disturbances were also seen not infrequently. For example, in a prisoners' working camp in Western Australia muscular pains and cramps were observed, owing to salt deficiency under conditions of great heat. In Queensland, at a physical training school, the A.D.M.S. of the 4th Australian Division carried out some observations on temperature of men undergoing training. He found that in hot weather with humidity at or above 74 per cent, the average rectal temperature in a group of men at rest was 100.4°F., whereas in temperate climates it was almost one degree less. Fifteen minutes vigorous exercise produced a rise of 1.8°F. in men fully clothed, but only 1.2°F. in men wearing only shorts.

Though severe instances of insolation or heat stroke were hardly ever seen, the observation was repeated that men suffering from the effects of heat showed exhaustion and were observed to sweat less, even to the vanishing point. In Mesopotamia in the 1914-1918 war K. G. Hearne found temporary suspension of sweating a reliable danger sign of impending heat stroke.

The waging of war in a hot climate produced some changes in the resuscitation of patients suffering from wounds involving much loss of blood. It was soon found, in the desert, that caution was necessary in applying heat to such men owing to the danger of increasing dehydration. It should be noted, however, that, as C. E. Corlette pointed out, a light covering such as a blanket tends to slow down heat loss, and that although heat is not easily transferred from the air to the body, this is possible if the skin temperature is low, say under about 90°F.

Great variation existed in the environmental conditions in operating theatres, not only in forward areas but also in base areas where the facilities for adequate ventilation were primitive. The provision of an air-conditioned ward in Lae for example was found very helpful to some severely ill men.

During the war, Professor D. H. K. Lee of Queensland pursued research on the reaction of man to tropical climates. One set of experiments was carried out on effective work in conditions of humid heat artificially produced. The salt-water balance was less strained than in conditions of dry heat. An attempt was made to come to some conclusions on acclimatisation, and it was found that in subjects living in Queensland there was a lower salt excretion, which indicated that acclimatisation had probably taken place already to some extent. O'Brien's work, outlined later, pointed to similar conclusions.

In the Royal Australian Navy, environmental conditions were, as in other navies, of great importance. Sometimes long periods were experienced in tropical climates with the ships under action conditions. In these circumstances internal ventilation was often very poor and the conditions below

decks extremely trying. One advantage was the possibility of discarding all heavy clothing. On the other hand, repeated changes of climate were often experienced, making it difficult to attain any degree of acclimatisation.

The medical officer of H.M.A.S. *Yarra* described the trying conditions near Basra, where the ship was stationed in mid river for long periods with a shade temperature usually 105°-110°F. and never below 100°F. Fortunately hospitals on shore were reasonably cool.

Similar conditions were experienced in numbers of other tropical areas. On H.M.A.S. *Lachlan* sweat rashes were much more common between decks; salt tablets—15 grammes twice a day—were administered to the engine room staff before they went on watch.

Surgeon-Commander J. M. Flattery described heat exhaustion on H.M.A.S. *Australia*. The closing down of the ship at night imposed considerable hardship owing to the lack of natural ventilation. The average temperature of the engine room was 117°F. and in certain parts the maximum was 125°F. No instances of heat stroke were seen, but heat exhaustion and gastro-intestinal disturbances and muscular cramps were all encountered. On occasion, the diagnosis between abdominal heat disturbances and other abdominal disease was not easy, but the response to salt was dramatic. Gastric types of the disturbance with epigastric discomfort, vomiting, headache, restlessness and irritability were found; there was occasionally an associated diarrhoea. The routine was adopted of giving each officer and man a half-teaspoonful of salt in water twice daily, using the tablets if possible. During the next two months only one instance of heat exhaustion was observed in a stoker who thought the salt might make him sick and had not taken it.

Flattery also points out that educational methods of preventing salt deprivation states are the most effective. Thus to ensure the routine taking of salt, a ration is better than adding salt to the drinking water.

Surgeon Lieut-Commander M. J. L. Stening also studied in detail the problems of salt deficiency in tropical climates; his study was based on two and a half years spent mainly in the equatorial zones. The subject of environment is of particular importance to a navy. It is further expanded in the Royal Australian Navy Medical History.

TROPICAL ANHIDROTIC ASTHENIA

J. P. O'Brien carried out an extended study on the general and specific effects of the condition called by him and Allen "tropical anhidrotic asthenia". Reference is made elsewhere to the work of Allen in the Northern Territory when he noted the occurrence of headache, exhaustion and shortness of breath in some men while working in heat. Most of the men concerned had suffered previously from prickly heat. The dry skin and gooseflesh type of rash were noticed to be characteristic sequels of exertion. Thirty-two other cases of this condition were described in detail by O'Brien, and many other instances occurred. In 1944 O'Brien prepared a memorandum on the subject for the D.G.M.S. of the Army for distribution among medical officers. The patients studied were seen in

parts of New Guinea, Morotai and Borneo. Numbers of observers have described various aspects of exhaustion states arising in the tropics, and contributions have been made to the literature in particular by American writers.

The symptoms of this state usually followed an attack of "prickly heat" or *miliaria rubra*. On the average, the subjects of the enquiry had been 6½ months in the tropics before they began to suffer from prickly heat. As a rule itching of the skin had improved or subsided by the time general symptoms arose, hence the skin manifestations were not a prominent feature of the patient's history, though important aberrations of the function of sweating were readily observed as will be seen.

The average course is as follows. The onset is insidious, the patient notices that exercise, particularly in the sun, causes throbbing headache, dizziness, shortness of breath, palpitation and later transient dimness of sight. Fainting does not occur unless the warning signs are not heeded and exposure to heat and exertion continues. The breathing increases in depth as well as in rate, up to 50 per minute, and the temperature averages about 100°F. The blood pressure does not appear to be much altered, though some response to exertion has been observed. Eosinophilia is common. Polyuria has been described, but this does not seem to be characteristic, and depends on fluid intake. Usually any readjustment has been made before the patient is seen. The urine is alkaline as a rule, and in the patient at rest there is some evidence of alkalosis. Dehydration and thirst do not occur. The face and forehead sweat profusely, the palms and the soles also sweat, and sometimes the axilla and the groin. Otherwise the trunk and limbs are dry and the skin feels hot, thick and dry. The covered parts of the skin are free of sweat, and numerous deep, dull white vesicles appear, but these do not surround the hairs as in true gooseflesh.

The diagnosis of this condition has led to some difficulty, as heat stroke, heat exhaustion and anhidrotic asthenia have to be separated. Heat cramps are of course distinctive. O'Brien points out that heat exhaustion is regarded by Ladell and others as largely due to dehydration, and that the profuse sweating which can be produced in the subjects of heat stroke is characteristic. He found, too, that moderate degrees of the characteristic changes in the skin occurred in numbers of troops ranging from 30 to 70 per cent, the high figures coming from the more active units. It was noticed that occasionally the anhidrotic state was mistaken for a psychiatric condition.

The explanation of this condition is not altogether clear. O'Brien suggests that the disturbance of circulation is due to dilatation of peripheral vessels. Though there is no reddening of the skin, biopsies reveal congestion in microscopic sections. He suggests, too, the possibility of reabsorption of sweat from the vesicles with some toxic action. The over-breathing might represent a panting response, but there is no evidence of this, though there seems no doubt that alkalosis is due to the respiratory disturbance. Tetany can occur in heat exhaustion, but it has not been

observed in this series, although it has been described in men observed in Iraq. A review of the literature shows considerable agreement between workers in different places. Rise in temperatures and lack of sweating have commonly been found, though a relationship of the latter to miliaria has not always been established. A sandy texture of the skin has been described.

O'Brien found that the condition lasted 4 to 12 weeks before normal sweating was restored, but one attack did not necessarily confer immunity. There was a tendency in some men for miliaria to recur in waves in which groups of sweat glands were affected in turn: in severe attacks the majority of the glands might be involved. Sometimes improvement did not take place, and the symptoms of the syndrome progressed. This may possibly be linked with the genesis of some of the more persistent and troublesome dermatoses in the tropics. For further descriptions of the changes in the skin and their possible relationship to other conditions the section on dermatology should be consulted.

Ladell, Waterlow and Hudson, in their observations in Iraq on water and salt balance, laid emphasis on the low urinary output both of water and salt in spite of high intake of water. They described a "type II" of heat exhaustion which is certainly identical with Allen and O'Brien's anhidrotic asthenia, and noted that these occurred in the latter part of the hot weather when prickly heat was in the healing stage. The question they have raised, whether severe miliaria is usually or inevitably followed by general symptoms, is answered by O'Brien in the affirmative.

Discussion of the causes of sweat failure and of its possible relation to fatigue of sweat glands leads to considerations of alterations in the water and sodium chloride balance and of aberrations or reactions in the central nervous system. It is evident that more research could be carried out with profit on this subject. *Miliaria rubra,* long thought to be merely a nuisance of hot climates, seems to be bound up with wider problems such as that of acclimatisation. Certainly it is suggestive to look at the sequence of prickly heat occurring some months after arrival in the tropics, followed in some persons at a shorter interval by asthenia, then circulatory and respiratory distress after exercise associated with anhidrosis of the covered areas of the skin.

COLD

Exposure to cold was not so troublesome a problem as exposure to heat, but some difficulties were encountered. After the Syrian campaign when troops of the Australian Corps occupied Syria as a fortress area, two winters were experienced. The cold in the mountain areas was sometimes severe and occasionally units were snowed in for a period.

The D.D.M.S. of the I Australian Corps in October 1941, issued detailed precautions to avoid trench foot and frost-bite. These in the main were regular exercises, changes of dry clothing, frequent inspections of the feet with protective applications of powder and oil, and the use of gum boots. Occasional instances were seen of trouble due to exposure to cold, but these were not serious.

In the Western Desert during the first Libyan campaign and in Syria, severe cold was encountered at night, and occasional instances of mild frost-bite were seen. Frost-bite was occasionally seen among men in German prison camps in Poland. Cold was also an occasional problem to be faced in the navy, but here, adequate protection against the winter was available as usual.

In the air force the same problem was encountered as in all air forces, that of coping with low temperatures with high elevation. These matters are dealt with in the Royal Australian Air Force Medical History.

It may be pointed out here, however, that in the transport of sick by air, cold was not unimportant. This was particularly so with sick men coming from tropical areas. When they were exposed to cold and a relative degree of anoxia, they suffered considerable discomfort. The lowered metabolism associated with oxygen lack and the interference with peripheral circulation and the loss of body heat by radiation, combined to produce unpleasant and sometimes even dangerous results. Such problems were met in the early days of air evacuation, as is told elsewhere. It should be noted also that the discomforts of cold in air travel at a fairly high elevation troubled not only the sick but the healthy. Soldiers transported by air often showed the need for a greatcoat by their blue shivering appearance even in the tropics.

Of course, these conditions could not compare with the severity of those encountered by aircrews flying at really high elevation, but the factor is one of considerable importance in relation to the sick. Though the subject of anoxia will not be dealt with in further detail here, it has become a very important environmental condition, not only in war but also under conditions of commercial flying.

MOTION SICKNESS

During the earlier days of the war, motion sickness was more important with navies and air forces than with armies, but with the development of combined operational manoeuvres it became very important to assault forces. In the Royal Australian Navy a special technical instruction was issued on sea sickness. In this was pointed out that the period required for adaptation is variable but is usually not less than three weeks. The percentage of those permanently un-adaptable to the effects of motion of a ship is given as only 5 per cent. General instructions were given including the advice that when early signs, such as pallor, yawning and sighing are noted, the man should be placed on some task requiring mental concentration and kept at work. The wearing of two abdominal belts, tightened over a pad, were also advised, and the instruction concludes as follows:

"As soon as any nausea is experienced—
Tighten the belts.
Refrain from smoking.
Find an interesting job to do or game to play, preferably in the fresh air and to windward of the galley and as near a point two-thirds aft as possible.
Reading a book is not good enough.

If nausea increases, watch the land or the horizon rather than the sea
Keep moving and do not lie down, except to sleep.
close at hand.
Walk about with the legs well apart.
Barley sugar may help if taken early.
In general, keep the stomach as full as possible with fruit, plain biscuits, strong tea or coffee.
Sling your hammock athwartships if possible.
If really sick it is too late for medicines.
Don't go to the Sick Bay, as the M.O. is probably sick too."

Special procedures were advised with soldiers in assault craft immediately before landing, and detailed instructions were supplied.

The most effective drug for the relief of seasickness has been found to be hyoscine, about one-hundredth grain of the hydrobromide, alone or in combination with hyoscyamine. Most of the effective remedies contain some such preparation. No extensive experience was gained in the use of hyoscine in combination with one of the special barbiturate drugs, such as "V-12" (ethyl β-methylallyl-thio barbituric acid). One difficulty found in landing barges was that of ensuring fresh air to men who were crowded together and often out of range of the breeze. For short trips of this description the amount of protection afforded by drugs of the hyoscine group was generally considered to be in the region of 80 per cent. A preliminary dose before embarkation repeated in six hours was often used: no drowsiness or affection of sight was observed.

Air sickness has engaged the attention of all air forces. In the Royal Australian Air Force it was found that many trainees so affected in their early days soon lost their tendency to be upset by the unaccustomed movements of an aircraft in rough weather. Squadron medical officers could obtain hyoscine hydrobromide in tablets containing 0.75 milligrammes which were found effective. An interesting point concerning the transport of the sick and wounded by air is that those who are severely ill were found to be seldom affected by travel sickness.

SOLAR RADIATION AND EYESIGHT

The effects of glare in the Middle East have been mentioned briefly in the section on ophthalmology, particularly with regard to its effect in making manifest discomfort due to refractive error. The R.A.A.F. took special interest in "surface brightness" as it was sometimes defined. R. K. Macpherson, working under the direction of Professor D. H. K. Lee of Brisbane, measured the surface brightness in several places in the South-West Pacific Area a little north and south of the equator. It was found that the surroundings had an effect often more important than latitude. White coral landing strips reflected light of an intensity almost as great as that from white cloud. Looking upwards usually produced glare more readily than looking down. It appeared that many factors had to be taken into consideration, such as the various kinds of radiation which might affect the eyes, including infra-red and ultra-violet rays, the existence of

contrast relief in the surroundings, the pigmentary equipment of the eyes, and lastly the mental attitude of the observer.

The subject though interesting medical officers caring for men on land, at sea and in the air under the unusual hazard of war is of special importance to the air force medical service.

Harmful effects from solar radiation causing photo-retinitis have been observed in servicemen and women, particularly those engaged on aerial lookout work. These are described in the section on ophthalmology.

PSYCHOLOGICAL EFFECTS OF ENVIRONMENT

Too much has been made of the effects of environment on the mental state of men on active service. The physical environment *per se* may of course be such as to favour malnutrition, fatigue or loss of sleep; it may afford greater risk of infectious disease; it may inflict considerable or even great bodily discomfort; but a good personality in the individual and good handling of the human community by its leaders should foster that high spirit which triumphs over hardships. It is of course desirable that men should not be left too long in isolated and uncomfortable places without relief, especially if they have too much or in particular too little to do. The moral environment is more productive of psychiatric disorders than the physical; it is particularly harmful for men to feel that their work or even their presence in a distant place is of little or no value. Yet most of the men who blame their surroundings for their mental incapacity are in truth unable either to support monotony, and restricted amenities, or to counter these evils by their own efforts. It is regrettable in current speech to use dangerous labels such as "tropical neurasthenia" or even the colloquial "troppo".

The navy furnishes proof of the value of the team spirit. Examples of this were seen in small ships particularly. For instance the crew of H.M.A.S. *Arunta* had perforce to live constantly on board for nearly a year, in the tropics, with no shore leave save during one period of a few weeks. This was necessary because of the prevalence of tropical diseases ashore, and although some of the three hundred men on this destroyer showed signs of mental and physical strain before they were relieved, efficiency was maintained under these trying conditions.

APPENDIX

Effects of Heat

The clinical conditions grouped under the above heading are dependent on high air temperature and may occur apart from the direct rays of the sun, as in the boiler rooms of ships, in mines, and even in barrack rooms and tents under exceptional conditions. Quite commonly the attack may start during the night several hours after sunset.

Important contributory causes are high relative humidity (wet bulb reading over 83°F.) and air stagnation, both of which interfere with the normal evaporation of sweat.

Other important predisposing factors are:—

(i) Deficient fluid intake. The fluid lost by sweating is not made good and dehydration results. This in turn leads to deficient or absent sweating, a most important factor in the causation of heat hyperpyrexia.

(ii) Deficient blood chlorides, due to a combination of:
(1) Deficient salt intake.
(2) Excessive sweating (most of the salt is lost in the sweat).
This again predisposes to diminished or absent sweating. (Clinical evidence of deficient blood chlorides is given by reduced or absent urinary chlorides).

(iii) Unsuitable clothing and housing.

(iv) Metabolic upsets, especially when associated with excessive alcoholic intake.

(v) Debilitating diseases.

(vi) Marked fatigue, often brought on or aggravated by strenuous exercise during the heat of the day.

(vii) Pyrexia from any cause, especially if associated with malaria.

(viii) Constitutional inability to sweat; also prickly heat and certain chronic skin conditions (i.e. ichthyosis).

(ix) Endocrine imbalance, especially increased thyroid and suprarenal activity (mild hyperthyroidism is common among young people recently arrived in a hot country).

(a) Clinical Varieties

Two major clinical groups must be distinguished.

The first, *heat hyperpyrexia* (classical heat stroke or thermic fever), is directly dependent on heating up of the body to a dangerous level and is usually preceded and accompanied by absence of sweating as an essential cause of the condition.

The second, *heat prostration,* results from a combination of:
(1) Dehydration, and
(2) Salt deprivation (Hypochloraemia).

The body temperature may be subnormal and the skin moist.

Cases of mixed etiology (i.e. collapse with high rectal temperature) are not uncommon; also, cases of heat prostration may develop hyperpyrexia and, conversely, cases of hyperpyrexia may suffer from collapse.

(i) *Heat-Hyperpyrexia,* a "sthenic" condition, usually of sudden onset, which may or may not have been preceded by prodromal symptoms. Is usually accompanied, if severe, by marked cerebral symptoms, and there may be an initial epileptiform seizure, or series of epileptiform attacks (occasionally terminating in *status epilepticus*). Coma or intense lethargy rapidly passing into coma; stertorous, often Cheyne-Stokes, respiration; cyanosis, which may be extreme; bounding, high tension, "cerebral" type of pulse; absent knee jerks, up-going plantars, all point to severe cerebral mischief. Accompanying these urgent clinical phenomena we have a dry burning skin and a markedly raised body temperature (i.e. 106°-110°F.), the extent and duration of which is of prime prognostic significance.

Many sub-varieties of heat-hyperpyrexia are described having relation to the chief presenting symptom, i.e.
(1) Asphyxial.
(2) Paralytic.
(3) Psychopathic.
(4) Heat Cramp.

A combination of (1) and (2) is common.

Heat Cramp, the result of dehydration and salt-loss, is specially liable to attack those (i.e. stokers on ships) in whom the heat-stroke has been preceded by intense and prolonged sweating.

Many minor cases of "heat stroke", grouped under the general term "effects of heat", are admitted throughout the hot-weather season. The chief symptoms are headache, often severe, dry, non-sweating skin, moderate fever (102°-104°F.) constipation, dysuria and frequency of micturition. Unfortunately this diagnosis is also

used during the summer months as a "scrap heap" for a variety of indefinite clinical conditions.

(ii) *Heat Prostration,* an asthenic condition, less dramatic in onset than heat hyperpyrexia and often occurring in debilitated individuals, is a state of clinical shock. Dehydration, due to excessive sweating, and hypochloraemia, mainly due to the same cause, are the chief factors in its etiology.

The chief symptoms are those usually associated with marked collapse: cold clammy skin (in contrast to the hot dry skin of hyperpyrexia), shallow sighing respirations, rapid thready pulse, often imperceptible at the wrist. The surface temperature is usually subnormal (95°-97°F.), although the rectal temperature may be high. In most serious cases, there is evidence of intense dehydration and of marked hypochloraemia (causing cramps in the limbs). The blood pressure is low; the skin is inelastic, and there is usually marked haemo-concentration. The patient may or may not have a clouded consciousness and be in a state of clinical "faint" but there is never the deep coma seen in severe cases of hyperpyrexia.

Minor instances of this condition, known as heat exhaustion (fainting in the ranks on a hot day, etc.) are common throughout the summer months (even in temperate climates), but the severer grades are just as urgent emergencies as the more florid cases of classical heat-stroke.

(b) Prodromal Symptoms

Although both varieties of "Effects of Heat" may occur "out of the blue" in apparently healthy individuals they are more likely to attack those debilitated by disease or other cause, or suffering from a febrile illness, especially malaria.

Prodromal symptoms precede the acute attack by hours or days in a proportion of cases, and are, when present, valuable sign-posts. Amongst common prodromata may be mentioned:

(i) Inability to sweat—an early and important symptom especially of heat hyperpyrexia.
(ii) Headache and/or drowsiness.
(iii) Temperamental changes (i.e. increased irritability)—valuable early sign when present.
(iv) Frequency of micturition, dysuria.
(v) Diminished urinary chlorides, an objective sign of great importance (less than 200 mgms. per 100 c.c. of urine and a total of less than 8 gms. in the 24 hours are said to represent the danger line).
(vi) Pain and cramps in limbs (evidence of dehydration and salt loss).
(vii) Vomiting and constipation (also important as predisposing).
(viii) Anorexia.
(ix) Rapid pulse, contracted pupils, absent or diminished knee jerks (said to be a valuable early sign).

(c) Differential Diagnosis

Many diseases and conditions (including almost the whole range of "cerebral catastrophes") may, at the outset, be clinically indistinguishable from "heat-stroke", but malaria, especially "cerebral" malaria, is by far the most important. Malaria may closely simulate or complicate both heat hyperpyrexia (malarial hyperpyrexia and cerebral malaria) and heat prostration (algid malaria).

Blood smears should be taken, and examined for malaria in all cases, and, unless malaria can be definitely excluded (the result of one negative blood smear is not sufficient evidence) the safest procedure is to give an intravenous injection of quinine, taking special precautions against increasing the already present collapse (see under treatment paragraph (d)).

(d) Treatment

This necessarily varies according to the clinical variety. In all cases, immediate removal to the coolest available location (i.e. heat-stroke centre if available) is necessary.

(1) *Treatment of heat-hyperpyrexia.* Rectal temperature should be taken in all cases (a body temperature over 108°F. is said to kill within the hour). The urgent necessity is to reduce the body temperature as rapidly as possible below the danger level. This may conveniently be done by laying the patient on an iron bedstead or charpoy with a light mattress or permeable matting intervening. His naked body is then sprayed with ice-cold water from an over-head douche (rubbing with ice is not advised). The body temperature should be carefully watched during this process and no further reduction of temperature should be attempted once it has been reduced to a safe level (i.e. from 109°-104°F. from 106°-102°F.). If too rapid and too great a reduction of temperature is attempted grave collapse may ensue.

If the surrounding air is saturated with moisture (i.e. relative humidity round 90% to 95%) it may be impossible to promote sweating by these means. The patient may then be put in a bath of cold, but not too cold water. Ice to the head and an ice-cold enema are valuable adjuvants in severe cases. Attempts to produce sweating by antipyretic drugs, e.g. pilocarpine, are dangerous and should not be attempted.

If, in spite of these measures and the reduction of temperature the patient remains deeply unconscious and cyanosed, with stertorous breathing, the removal of 15-20 oz. of venous blood and its replacement by normal or hyper-tonic saline solution with 5% glucose is often effective.

In the event of circulatory failure, coramine or digitalin (not strychnine, which is a convulsant) may be given.

Respiratory failure, a not uncommon event, should be treated by artificial respiration, prolonged for several hours if necessary. If coma persists for several hours, lumbar puncture and the removal of 10-20 c.c. of C.S.F., if under pressure, may relieve this symptom. (Lumbar puncture should not be attempted too early. The whole brain is oedematous in the early stage, and it is only later that the fluid in the sub-arachnoid space is under pressure. Lumbar puncture too early may, by producing a "pressure cone" be itself the direct cause of death by paralysing the vital centres in the medulla).

It is important to keep a careful watch on the temperature of apparently recovered cases, since recurrence of hyperpyrexia with its accompanying symptoms is by no means uncommon and may lead to a fatal issue. Don't keep patient too long lying on back or hypostatic congestion of lungs may result. Turn on side or face frequently.

(ii) *Treatment of Heat Prostration.* If of severe degree the urgent need is for restorative measures and for the replacement of fluid, and especially of salt lost by excessive sweating. Unless the body temperature is high (estimated by thermometer in rectum), there is obviously no need to reduce the temperature, often the reverse, and a blanket and hot water bottles may be required. Coramine may be given to conscious patients for its stimulating effect. If able to do so the patient should be encouraged to drink large quantities of weak saline drink (¼ teaspoon of salt to the pint of water or imperial drink). If the condition is serious and especially if marked dehydration is a feature an intravenous infusion or normal (or hypertonic) saline solution with 5% glucose is urgently called for.

In either condition, if it is considered necessary to give intravenous quinine, precautions should be taken against aggravating the state of shock which may already be present. In collapsed cases, especially if there is much dehydration, the quinine (8-10 grains) is best given in 1-2 pints of normal saline with 5-10% glucose, to which has been added and well mixed with it 10 m.ms. of adrenaline or 1/2 c.c. of pituitrin. In collapsed cases all infusions should be given at blood heat.

(iii) *After Treatment.* Rest in a quiet darkened room. Cases of hyperpyrexia, especially, should not be allowed up too early or intractable headache may result. Headache best treated with luminal or bromide. Heat-stroke cases are particularly susceptible to hot weather conditions and should, if possible, be sent to a cool climate for the remainder of the summer. Alcohol should be avoided.

(iv) *Heat-Stroke Stations.* These are advisable in certain localities (i.e. large camps and hospitals) during the hot summer months. They are for the urgent treatment of all cases of "Heat-Stroke" in the vicinity and should therefore be

centrally placed and sited in a relatively cool locality. There should be a trained orderly in constant attendance during spells of hot weather and a daily provision of ice should be ensured. The position of the station should be known to all ranks and the medical officer on duty should be within easy call. The equipment varies according to the size of the station, distance from hospital, where partially recovered cases can be transferred, etc.

(e) Prophylaxis

(i) Simple lectures to all ranks on the causation of heat-stroke and its prevention should be given before the onset of hot weather conditions.

(ii) A careful look-out by medical officers for men exhibiting prodromal symptoms (examine urine for diminished or absent chlorides in doubtful cases).

(iii) All strenuous exercise reduced to a minimum during the heat of the day. N.B. This does not mean that men should remain cooped up in darkened barrack rooms with little to do but lie on their beds and meditate many hours during the day. They are far better employed performing light duties in the open, in the shade, if possible.

(iv) If strenuous exercise in the hot sun with consequent excessive sweating is unavoidable, men should be encouraged to drink weak *saline* drinks (salts ¼ teaspoon to the pint of water or weak tea) to replace fluid and salt lost by sweating.

(v) Importance of avoidance of alcohol during the heat of the day to be impressed on all ranks.

(vi) Clothing should be light, permeable, and loose, to allow free ventilation of the body surface.

(vii) Careful routine attention to and cleanliness of skin. The use of a simple dusting powder over parts liable to sweat.

(viii) Enforcement of careful march discipline, e.g.:

(1) Ventilation of ranks when marching (i.e. changing files after each halt; opening up on either side of road when possible).

(2) Full use to be made of halts for resting and cooling.

(3) Water bottles to be used only at halts, and then just sufficient weak saline water (or weak saline tea) consumed to replace fluid and salt loss.

N.B. The drinking of large quantities of unsalted water is harmful. It gives no great relief from thirst and tends to make men vomit.

(4) Long marches during the heat of the day to be avoided or reduced to a minimum. If unavoidable, men should drink weak saline water or weak saline tea.

(ix) Hospital precautions during hot weather.

(1) Heat-stroke stations prepared beforehand when considered necessary.

(2) Operations and anaesthetics reduced to a minimum during the heat of the day.

(3) Careful and frequent checks of temperature of all patients in hospital, especially febrile cases (malaria). A mounting temperature in an already febrile patient may be a danger-signal of impending heat-stroke.

(4) Certain drugs, i.e. atropine (reduces sweating); thyroid (increases metabolism), strychnine (convulsant) are best avoided or reduced to a minimum.

(5) Individuals with constitutional inability to sweat are in special danger of heat-stroke and may have to be retained in hospital throughout the hot weather or sent to a cooler climate.

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CHAPTER 30

POISONING

1. VOLATILE POISONS. BENZOL AND TOLUOL.

THE hazards associated with the use of volatile substances such as the aromatic naphthas, like benzol and toluol, are well known. Cases of blood dyscrasia due to this cause are occasionally reported in civil life, and in a few instances these occurred in the Services also. Deaths also occurred from aplasia of the bone marrow, in circumstances which apparently precluded the possibility of exposure to toxic substances. The cause of these was just as obscure as similar happenings in civil life, but the sensitiveness of the bone marrow to certain chemical substances and to some nutritional disturbances always suggests the propriety of looking for a toxic cause.

A soldier died from aplastic anaemia some time after an apparently brief exposure to benzol; this was accepted as due to benzol poisoning in a very susceptible person. In 1944 an airman died of acute thrombocytopaenia and aplastic anaemia. He had been working for some one and a half hours a day over a period of over two months in a workshop where engine parts were cleaned with a fluid of high benzol content. A special investigation was sponsored by the D.G.M.S., R.A.A.F., to determine whether men employed in such workshops were exposed to hazard, and whether any periodic check on their blood should be made. Conditions in painting and spraying shops were also investigated. Blood examinations were made of men making any contact with benzol. Counts were made of the red cells and platelets, total and differential counts of the white blood cells were made, haemoglobin and haematocrit estimations were carried out, and calculations of the mean corpuscular volume, haemoglobin content and concentration.

Owing to a lack of agreement in the literature, difficulty was found in setting a standard by which the early signs in the blood of benzol poisoning could be recognised. Standards were determined for healthy controls, who were members of the R.A.A.F. not exposed to any industrial hazard. These showed a striking difference between the blood pictures of 300 controls and those represented by the standard figures of Whitby and Britton. Full medical and occupational histories were taken of the contact groups and also of control groups drawn from non-flying units. These results were subjected to statistical analysis.

It seemed probable that individual susceptibility to benzol vapour varied considerably. The various fluids used in the R.A.A.F. under investigation were found to differ considerably in their content of aromatic hydrocarbons, ranging from 16 to 56 per cent. Estimation of the vapour content of the aromatic hydrocarbons in the atmosphere of workshops showed variations from 0 to 1,400 parts per million, according to the place and

circumstances of testing. For most of the time concentrations did not exceed 10 to 35 parts per million, and higher concentrations existed only for brief periods. This investigation did not reveal any need for routine blood examinations of members of the R.A.A.F. employed in cleaning and painting workshops, but emphasised the need for the establishment of Australian norms for blood pictures. In view of individual variations in susceptibility to benzol vapour strict attention was necessary to the safety precautions laid down for workshop practice. The published results of this enquiry by M. Hutchings, S. Drescher, F. B. McGovern and F. A. Coombs pointed out, too, that new processes involving the use of new solvents were constantly being introduced, making close cooperation imperative between technical and medical staffs.

2. METHYL ALCOHOL

Many minor forms of toxic gastritis or gastro-enteritis occurred as the result of drinking "home brews" of various kinds. Optimism and ignorance led men to drink fermented liquors which must have contained a mixture of alcohols and by-products of varying toxicity. This happened occasionally in the islands, where the difficulty in obtaining alcohol was the spur to experiments in brewing. The resultant disturbances were only temporary and seldom needed special treatment, but men were occasionally admitted to hospital. On the hospital ship *Manunda* Major Rosebery reported a state of confusion in men who admitted drinking "jungle juice"; they had sluggish deep reflexes, impaired memory, unsteadiness and delusions. These manifestations seemed to be out of proportion to the amounts consumed, but they cannot be classed as being due to any other cause than alcohol in general, except that there was clinical evidence of slow excretion.

Much more serious were the results following the ingestion of methyl alcohol or methanol. This substance is rapidly absorbed but very much more slowly excreted from the body, where it breaks down into other toxic substances like formic acid. The consumption of quantities less than the usually accepted lethal dose of 100 to 250 millilitres has been reported among Australian soldiers without harmful effect, but there is apparently considerable variation in the power of different individuals to withstand or detoxicate methyl alcohol.

A series of eight cases was reported by Major J. H. Colebatch in Balikpapan. The patients were treated under action conditions in a casualty clearing station, where full investigation was difficult. Methyl alcohol was obtained by three groups of men from drums captured from the Japanese, and consumed diluted with lime juice and water. Six men died. One man was apparently almost unaffected by some ten to twelve ounces of methanol drunk one and a half days before, though this amount was fatal to all but one other. Nausea and vomiting appeared after a latent period of sixteen hours, and amblyopia was then observed. The nervous system was seriously affected, as evidenced by stupor, coma and fits, and the optic discs were swollen in three instances. Treatment

given included continued gastric lavage, intravenous administration of alkalies, free glucose fluids and lumbar puncture. Post-mortem examination showed congestion of the digestive organs, kidneys and brain. One of the two patients who recovered still had optic atrophy of one eye five months later.

In June 1944 seven men from Keppel Harbour camp on Singapore Island were treated for methyl alcohol poisoning; five were Australians and two Dutch. One of the Dutch died soon after admission to hospital, all the others recovered. Most of these men had toxic amblyopia in varying degrees; one had some contraction of the visual fields some time later, but central vision was normal.

Another outbreak of methyl alcohol poisoning was observed in a working camp at Singapore in February 1945. Cotter Harvey reported that over 150 men, Australian and Dutch, were affected on one occasion after taking the alcohol in tea. The latent period here was twenty-four hours, when gastro-intestinal disturbances were noticed, and next morning one man died suddenly. It was then found that over 150 men were affected with gastro-intestinal upset or blurred vision. Nine were seriously ill and were admitted to hospital. Two died within a few hours. The remainder were treated with gastric lavage and alkalies; their urine contained formic acid, as did also the cerebro-spinal fluid, which was under increased pressure. All these made good recoveries with full restoration of eyesight. The amount of methyl alcohol taken was small; in no instance did it exceed two ounces and the average appeared to be about half an ounce. It is probable that some of the men were unduly susceptible and in all the men and particularly in those most affected it seems probable that lowered nutrition decreased their tolerance.

A warning was issued in the Routine Orders of the 2/14th Australian General Hospital for 24th/25th October 1945, of the danger of drinking local spirits on Singapore Island. Up to 15th October, sixty-four men had been admitted to hospitals in the area suffering from the effects of drinking spirits which contained methyl alcohol. Twenty-eight deaths of servicemen of various nationalities were reported and two among civilians. Permanent blindness was caused in two instances. Tests of the liquor consumed showed that one drink might cause blindness and two might be fatal.

3. ETHYLENE GLYCOL

S. F. McDonald reported seven cases of poisoning by ethylene glycol, with four deaths, in members of the R.A.A.F. This liquid is the chief constituent of an anti-freeze mixture used in liquid-cooled aero engines, and has neither colour nor odour, but a warm bitter-sweet taste. The lethal dose is said to be about 100 millilitres. Like methyl alcohol, it has a predilection for the nervous system. In this series the liquid was drunk as part of a New Year's Eve celebration, and was mixed with lemon powder in water. One man was unaffected till the next day, when he had vomiting, and the following day the signs of a severe glomerular

nephritis appeared, from which he later recovered. Two others recovered after severe vomiting and considerable general disturbance but no focal signs. In the four fatal cases, congestion of the digestive and respiratory organs and the kidneys was noted. Choking of the renal tubules with oxalate crystals has been described, but was not found in this series. All the men who died lost consciousness early.

4. TRI-ORTHO-CRESYL PHOSPHATE

Perhaps the most curious neurological condition seen in the Australian armed forces was due to the effects of tri-ortho-cresyl phosphate. This substance attained some notoriety in the United States of America during the prohibition of alcohol, when it was used as an adulterant in ginger drinks. It caused severe symptoms of motor paralysis, known as "jake" paralysis, which was characterised by early selection of the neurons of the lower limbs, followed by wider involvement, sometimes including the pyramidal tracts. The paralysis was symmetrical and improvement was slow. Residual damage in the severer grades caused muscular atrophy affecting both upper and lower extremities, with some spasticity of the gait.

Three patients were admitted to the 113th Military General Hospital, Concord, Sydney. Subjective symptoms in the legs were followed by foot drop, weakness and fibrillation of the calf muscles and loss of power in both hands. No definite objective sensory phenomena were noted. The symmetrical distribution of this motor neuron lesion suggested a toxic cause to Lieut-Colonel Noad and Captain Helen Taylor, and its strong resemblance to "jake" paralysis led to careful enquiry into possible sources of such a poison. A common feature was that each patient was under treatment for gastric or duodenal ulcer and was taking magnesium trisilicate. Each stated that he had noticed an unpleasant taste in the powder: one thought it resembled carbolic. Enquiry revealed that a fourth man noticed identical symptoms a week after his discharge for duodenal ulcer and had been admitted to a Repatriation Hospital, where similar findings were noted. All the magnesium trisilicate held by the hospital was examined, and in portion of this Dr Adrien Albert found 2.6 per cent tri-ortho-cresyl phosphate. The taste and smell described were not due to the substance itself but to other cresyls formed by hydrolysis. No contamination with other drugs of the cresylic acid type could have produced tri-ortho-cresylic acid in this way. No further samples of the magnesium powder were found to be contaminated, and with one exception no further cases were discovered. This occurred in an officer of one of the women's services, who unofficially obtained magnesium trisilicate from the hospital and took it for indigestion. She suffered a slight motor weakness in the lower parts of both legs which later disappeared. The clinical progress of the condition was slow, particularly in the patient first and most severely affected, but gradual improvement took place with some residual weakness.

Full enquiry failed to prove how the tri-ortho-cresyl phosphate contaminated the trisilicate powder. The admixture was observed on analysis

to be patchy and it was found that wartime stringency obliged large quantities of the trisilicate to be placed in a rather permeable container made of loose-meshed sacking. Lorries carrying such packages also carried many other commercial chemical products, including tri-ortho-cresyl phosphate, which is largely used as a plasticising agent in industry. It seems likely that contamination occurred in this way. The particular interest of this curious accidental happening lies in the value of careful clinical examination allied to a keen appreciation of the possibility of a common cause for a distinctive and unexplained syndrome.

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PART II

SURGICAL

CHAPTER 31

WAR WOUNDS

IN considering the treatment of war wounds it is simplest to regard the prototype of battle injuries as an uncomplicated wound of soft tissues, that is, of skin, subcutaneous tissues, fascial planes and muscle. The difficulty and complexity of surgical treatment are greatly increased by involvement of bones and joints, major blood vessels and nerves, or the head, the thorax and the abdomen with their contained organs. Every type of injury produces individual problems of expert attention and of nursing, and the time and method of transport of patients before and after operation demand special care. The growth of surgical knowledge and the development of highly technical methods in delimited fields have resulted in great expansion of surgical services in war, particularly in the more settled areas behind the forward battle zones. Nevertheless, it is still an important principle to regard the relatively simple flesh wound as setting a therapeutic standard, a basis for all wound treatment.

It is not easy to deal with the evolution of the treatment of war wounds in the 1939-1945 war from a strictly chronological point of view. At first sight it may appear that this surgical evolution centres round the introduction of sulphonamides and penicillin. It is true that the concept and practice of chemotherapy have marked an epoch in the history of medicine. Some surgical techniques have been revolutionised by penicillin, yet it is important to remember the other factors in surgical success, some revived from the half forgotten struggles toward the light in 1914-1918, others established by experience under the altering conditions of 1939-1945.

At the beginning of the war military surgical knowledge was little advanced past the standard reached in 1918. The 1914-1918 war saw a great advance from the apathetic beginning of that period, and excision with delayed primary suture was at last established as practicable in 1918. The ultimate goal, excision and primary suture, regarded as a crime a few years earlier, was seldom possible, but was regarded as the ideal towards which surgery was tending. Carrel and Dakin not only stimulated the use of antiseptics, but emphasised the caution necessary to maintain the vitality of those allies of repair, the tissue cells. The use of their method, controlled by bacteriological tests, made secondary suture a common procedure.

Between 1918 and 1939 these lessons were applied in the practice of traumatic surgery to some extent. Incidentally it is sad to reflect that apart from war, the experience of the traumatic surgeon is gained largely from efforts to repair the ravages wrought by modern forms of transport, particularly motor vehicles. Later, the Australian Army in the Middle East was to be seriously impressed by the wastage of soldiers from traffic accidents. During the earlier part of this period 1918-1939 Winnett Orr pursued his work on the closed treatment of osteomyelitis in long bones,

and his principles were followed in the handling of compound fractures and large soft tissue injuries. This method is of course quite a distinct addition to the techniques of excision and suture.

The Spanish war gave opportunity for evaluation of surgical methods and Trueta and others attracted the attention of the surgical world by the encouraging results obtained by excising all damaged tissue, and enclosing the part in plaster without suturing the wound. Bombing of cities in Spain showed how disruptive was the action of irregular fragmentary missiles, producing wounds more damaging than civil injuries in peacetime could show.

Resuscitation by the use of parenteral fluids, chiefly blood, made major advances during this period too, and the accurate knowledge gained of the degree and rate of fluid replacement required in conditions of medical and surgical shock was of untold help to the surgeon, even though some of the earlier civilian teaching was modified by military practice.

But when we return to the problem of the treatment of what may be called the basic damage of the war wound we find in 1939 a feeling of uncertainty. Chemotherapy with the sulphonamide drugs raised hopes that this might be a potent weapon against the bogey of infection, but the memories of 1918 enjoined caution. Military surgical methods in 1939 were substantially those of 1918: the organisation for their application was essentially similar. Surgeons in 1939 could not foretell if they would have to deal with such great numbers of casualties as in 1914-1918, or cope with wounds inflicted by missiles of all shapes and sizes, and heavily contaminated with the debris of soiled battlefields as in Gallipoli and France. There was little doubt, however, that infection, shorn of most of its power in civil surgery by aseptic techniques, would again be a menace. As Graham Butler truly pointed out, in 1914 there was a lack of understanding and experience what to do in the face of sepsis. By 1917 the doctrine was firmly founded that thorough surgical preparation was necessary of the damaged tissues for their work of repair, and "excision" of wounds, advocated by Milligan and others against opposition at a much earlier stage, at last won its place. This practice, advocated in the Napoleonic wars, was thus belatedly recognised. In 1939 it was known that when wounds were the source of their own infection hopes of sterilising them by antiseptics were doomed to be shattered.

However, there was still some lack of clarity in the means by which such preparative surgery could, with the help of the chemotherapeutic methods then available, become reparative. Surgeons who had learnt valuable lessons in the previous war did not always realise that the semi-static warfare of the Western Front had imposed on the minds of administrators its pattern of transport and moving of the wounded. In 1939 modern transport had revolutionised war, and the treatment of war wounds needed revision rather because of the effects of mobile warfare on the steady working of medical units than because of scientific considerations. One lesson taught by Winnett Orr and others in the later stages of the 1914-1918 war was not absorbed by all in spite of its importance, the

value of immobilisation of adequately drained wounds in plaster casts. Trueta in Spain further extended the idea to the treatment of recent wounds, and its value was apparent in securing comfortable transport and minimal interference for the wounded. His experience was so recent when war broke out in 1939 that the impression was fresh in the minds of those who realised that soon they would be treating wounds received not only in the field, but also in bombing raids in centres of civil population.

In Australia in 1939 a new edition of the *Manual of Injuries and Diseases of War* (*Australia*) was published, based largely upon the British *Injuries and Diseases of War*. The methods of wound treatment described here were simply those of 1918, and the accent was not placed on such aspects as Trueta's work on immobilisation and the possible advances of sulphonamide prophylaxis and therapeusis. Excision of the wound was rightly emphasised as a major advance in the previous war. Trueta's own summary in 1939 was more comprehensive than the advice in this manual and ran as follows. Early surgery was the watchword: after cleansing, shaving and skin disinfection, the skin edges were excised and then all non-viable muscular and cellular tissues, as judged by the contractility, colour and bleeding of muscles, the wound was opened for drainage, most bone fragments were removed, a fracture was reduced by traction, a dressing applied, and the limb encased in plaster.

In addition to this information available to Australian surgeons, Sir Thomas P. Dunhill, who was acting for some time in 1939-1940 as Consulting Surgeon to the A.I.F., sent from London to Australia detailed accounts of recent experiences and advances in war surgery. In this way recent trends in traumatic surgery were made known to the officers of the A.A.M.C. and some opportunity given to form judgments of the advantages and drawbacks of plaster immobilisation, the treatment of burns, the current views on amputation and other important subjects.

Before campaign experience in the Middle East is discussed some reference may be made to the confusing terminology of wound treatment. *"Débridement"* and "excision" have been used as though interchangeable. It is rather futile to attempt an apt translation of *"débridement"* as writers differ in their ideas of the measures it implies regardless of its derivation. Trueta defines it as including "the removal of all foreign matter, the excision of all the tissues immediately surrounding the wound, including devitalised soft parts in the vicinity, and the opening up of cellular spaces". Excision *en bloc* is obviously impracticable in most instances, but the word is taken to mean the removal of a thin skin edge where this is dirty or ragged or devitalised, and also of such other tissues as are judged incapable of survival, and infected. The operation is logically extended to the relief of present or expected pressure by swelling, and to the sacrifice of functional tissue which shows evidence of a dangerous type or degree of infection, as in muscle infected by gas gangrene.

"Primary" and "secondary" suture also require some definition, especially since the introduction of the somewhat contradictory term "delayed primary suture". Technical Instruction (M.E.), No. 20, in forbidding

primary suture in battle casualties pointed out that it is a frequent cause of bad results, and in wounds of limbs may necessitate amputation. "There is always another day in which either to act or regret—a secondary suture can later be performed". Secondary suture was taken to be repair by suture of a wound which had begun to granulate. Delayed primary suture meant the closure of a wound within a few days of the injury.

WOUND TREATMENT IN THE MIDDLE EAST

At the end of 1940, the time of personal testing and proving arrived when the first campaign in Libya and Cyrenaica began. The conditions under which forward surgery was carried out there varied according as the military situation was one of movement or not. The prime difference from the practice of the last war was the attachment of surgical teams to field ambulances. The most important problem in surgical treatment in the desert was to decide whether to pass wounded men over a long rough route to a casualty clearing station, or to risk holding up the necessary movements of the main dressing station during the patient's post-operative period. This is dealt with in more detail in the account of these operations (Volume II).

The Australian medical services attached to the 6th and 9th Divisions A.I.F. enriched their experience in this campaign by working under conditions of rapid movement in victorious pursuit, of temporary immobility, of equally rapid movement during retirement and finally of siege in Tobruk. During these operations, wounded were removed by road, rail and sea, and in only a few exceptional instances by air, to the intermediate units and to hospitals in Alexandria and Kantara and also in Palestine. Then came the brief valiant episode of Greece in which the surgical work was carried out in field ambulances and one casualty clearing station, and finally, when retirement was imperative, in one hospital, some of whose staff were taken prisoner, much to the benefit of the wounded. Almost at the same time, the 7th Division A.I.F. engaged in the attack on Syria, a brief campaign in which, after the first difficult stage of evacuation of the wounded, the routes to hospitals in Palestine were disposed according to the method of the military manuals for the first time. The end of this campaign marked an epoch, and although the largest set battle in which Australian troops participated in this war, El Alamein, introduced some new features in details of surgical treatment, the policy laid down by judgment and general knowledge in 1940 was consolidated into the practice dictated by experience by the end of 1941.

The surgical creed of the A.I.F. was simply expressed at this period in the Technical Instructions, Nos. 20, 21, 22, 23 and 24, for the A.I.F. in the Middle East.

Instruction No. 20 began thus:

"The following simple instructions will act as a guide for all those who have not had previous experience of war wounds. Experience will no doubt lead to modification of technique. Until that experience has been gained, it is recommended that the well recognised procedure detailed below be adopted."

The primary treatment thus laid down consisted of toilet and excision of the wound, placing no sutures except in wounds of the skull, thorax, abdomen or large superficial joints like the knee joint, and, after the first 36-48 hours, in amputation flaps. Sucking wounds of the chest, in Australian opinion, required sutures; plugging with bandaging or strapping was found unsatisfactory. Wounds of the face and jaw also required retaining sutures. It was emphasised and not without need, that dressing wounds with "Vaseline" and gauze does not mean packing them tightly with gauze, but simply loosely filling the space with "Vaseline" and covering with a few layers of gauze. This was particularly important when a plaster was applied. Where this had been done, and when any large wound had been excised the patient was retained for observation for twenty-four hours to ensure that the plaster was not constricting the limb, and that there was no risk of reactionary bleeding. This instruction was issued because it was learned that some medical officers were contemplating the trial of primary suture in wounds of the extremities. Instructions were also given for the handling of fractures of the upper and lower extremity in the field, wounds involving large joints, wounds of the face, jaw and mouth, wounds of the chest, and burns. These will be dealt with later in the appropriate sections on regional wounds.

Controversy in and out of Australia centred for a time on the question of primary suture. During the 1914-1918 war, this had suffered ups and downs, but with the improved methods of the later period was being regarded as an occasional method of choice by the end of the war, and as having some value in selected injuries in civilian practice. H. R. G. Poate, Consulting Surgeon to the R.A.A.F., writing in Australia defended primary suture, with proper safeguards, but Colonel W. A. Hailes as Consulting Surgeon to the A.I.F., forbade it strictly except as laid down in the instructions quoted above. These two points of view were not irreconcilable and Hailes could not do other than lay down a definite safe rule, the only safe rule at that particular surgical period in the Middle East. Care was taken to acquaint surgeons in Australia of the methods found most valuable in the Middle East. Hailes described these in regular letters to Major-General Maguire, D.G.M.S., during the latter part of 1941. These accounts followed up the methods used till the wounded man reached the base. This was stressed as important, for although the functions of the forward surgeon were limited by considerations of movement and nursing, the goal of rapid and complete restoration of structure and function was always to be kept in sight. The establishment of special sections in hospitals helped to keep prominent this aim in treatment, particularly a facio-maxillary (plastic) unit, and others for orthopaedic work and fractures, and to a less official extent, for wounds of the head and chest.

Opportunity was taken during the early campaigns to test the value of closed plaster: on the whole good results were obtained. Reference has been made above to the precautionary instructions concerning possible constriction of a limb by an encircling plaster. Some aspects of plaster

are better discussed in dealing with injuries of limbs and long bones, though the general principles apply more or less to all wounds for which plaster was used. By the time wounded arrived in base areas one of the drawbacks of plaster immobilisation in a hot climate became evident, as the odour soon became offensive. Experience showed that an offensive discharge seeping through the plaster and a coincident rise in temperature and pulse rate did not necessarily mean a serious infection. Removal of the plaster, cleansing and redressing often revealed a wound which could quite justifiably be recased in plaster. Major Brooke Moore, commanding the portion of the 2/5th Australian General Hospital in Greece after the withdrawal of the Allied forces, found that the particularly voracious local bugs invaded plasters to an extent that was a serious objection to the method, even had local supplies of plaster been adequate. In the Middle East naphthalene was issued through the Army Service Corps, and this helped to mitigate the odour of plasters; half a handful of crystals was placed over the part of the plaster covering the wound before the last few turns of the bandage were made.

Apart from such difficulties plasters needed a certain amount of supervision during transport of patients, and it was never desirable or safe to disregard any complaint of discomfort. Dunhill in one of his London letters said:

"Simple treatment, plaster and sulphanilamide give comfortable and safe transport, but the patient should not be left too long without removal of the plaster, inspection of the wound and treatment according to the condition found. This is not a disproof of the Trueta method. The Spanish wounded were close to a hospital where skilled surgeons were able to give the full treatment at a very early stage."

Colonel Hailes, writing to Major-General Maguire on 10th August 1941 about the experiences gained to that date, spoke more definitely:

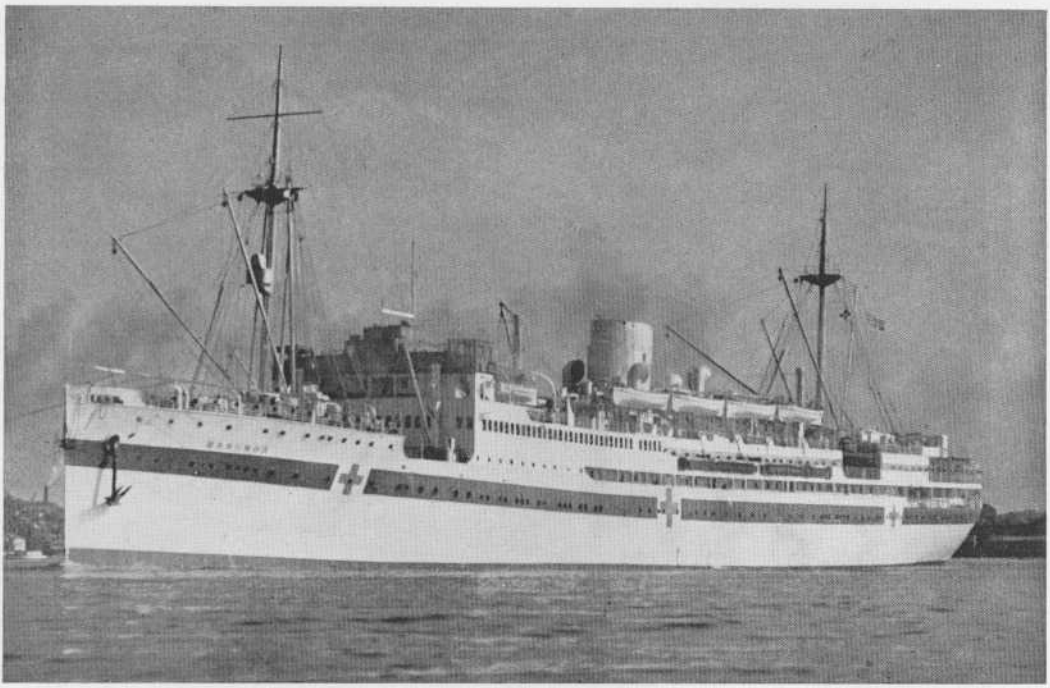
"The first plaster that is put on is for travelling only: tell them that there must be something unusual about Spanish patients, but Australian surgeons cannot correct the position and keep it corrected in plaster. The beautiful picture painted in some of the recent text books will need to be forgotten, at least in part."

This warning was of course not intended to discourage the value of closed plasters used properly, provided the method was not regarded as a talisman in the quest for repair. The wound cleaned, excised and kept secure from movement and from extraneous sepsis, was given a good start: much often remained to be done even after local defence against infection was established. Observation in base areas showed that prolonged immobilisation in plaster had many drawbacks, notably the slowness of healing by secondary intention where skin loss was considerable. Large lacerated wounds, as Rank pointed out, sometimes showed a large surface of exposed muscle which closed in and left a small final wound to heal. Others with loss of much skin often left unstable scars. Other causes of delay in healing or soft tissue wounds were not dependent on the size or nature of the wound, such as the presence of fragments of foreign material, sloughing of tendinous structures and sepsis in bones. The ubiquity of infecting organisms such as streptococci and staphylococci was a constant threat to healing.



(Australian War Memorial)

Transferring wounded from barge to ship at Tobruk.

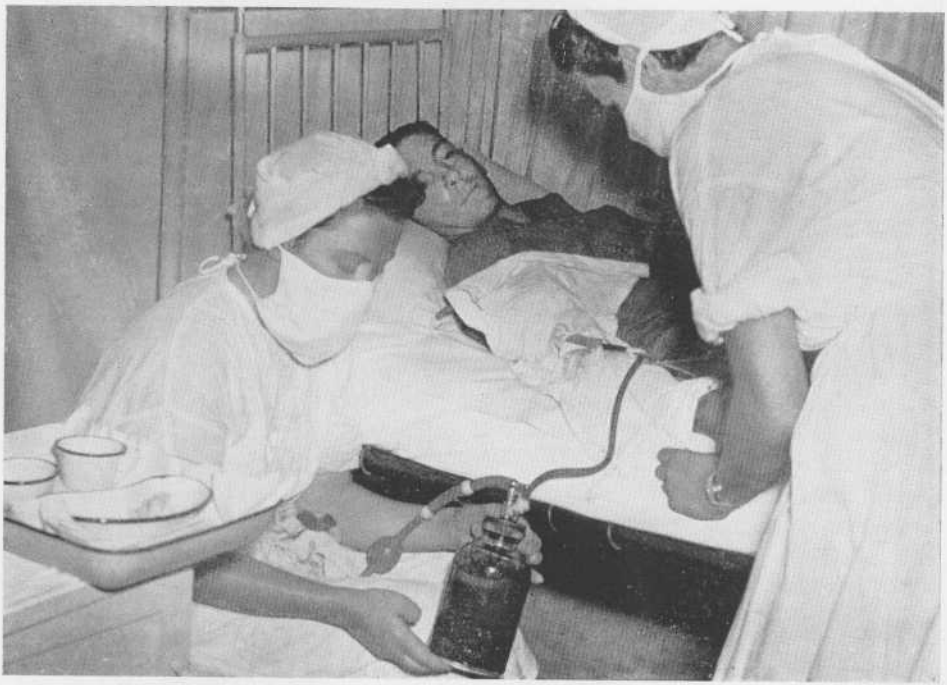


Hospital ship *Manunda*.



(Australian War Memorial)

Blood transfusion at C.C.S. in the Western Desert.



(Australian War Memorial)

Unit collecting blood from army personnel at a forward operational base —Netherlands East Indies.

The experience gained in the first desert campaign showed that excision of wounds as practised by the surgical teams attached to the main dressing station of field ambulances was nearly always adequate. As time went on and results could be checked by the career of the patients in base hospitals an increasing number of young surgeons became familiar with the correct technique under the tutelage of seniors. The thoroughness of this early surgery had an excellent clinical and educational influence. The importance of detail was stressed. Excision of the skin edge depended on the site of the wound and the condition of the skin and deeper tissues. All bruised pieces of muscle or fascia were removed, and blood clot cleared from recesses of the wound. Incisions were made, the wound being extended if necessary, in order to obtain access; these were specially needed when the damage, as so often was the case, was greater than the size of the wound of entrance suggested. Deep fascia was slit to prevent subsequent compression of soft tissues. Foreign bodies were removed as far as possible, particular attention being paid to fragments of clothing and embedded dirt. Loose long fragments were usually removed unless they had sufficient promise of vitality to be useful in repair. Such operative procedures had always to be based on sound anatomical and physiological principles. Important structures such as leashes of nerves and blood vessels had to be remembered and respected. It was sometimes desirable to explore such structures for possible damage. The amount of soft tissue excised was influenced too by the degree of deeper damage, such as fractures of bones. In fact it later became an aphorism that after operation on a wound causing compound fracture of a long bone it should be possible to see the fracture site. Surgical treatment of wounds other than first aid demanded a ready anatomical knowledge and adequate operative experience.

From the beginning sulphonamides were given to all wounded on admission to a forward operating theatre. At first the practice varied in amount and detail. In some medical units a single daily dose of five grammes was used; in others an initial dose of two grammes was followed by one gramme every four hours. Sulphanilamide or a mixture of sulphanilamide and sulphapyrazine was also introduced into the wound and dusted on the surface. The prophylactic value of these drugs was not doubted by surgeons, though at first it was overrated, for the dust of the desert, though all pervading, was bacteriologically more or less harmless. Yet during the Syrian campaign at a later date where the terrain was cultivated and in places closely occupied, only seven cases of gas gangrene were seen among 1,500 battle casualties. It is not suggested, however, that this low incidence was due only to the administration of bacteriostatic drugs.

After the whole experience of the Middle East had been assessed, an instruction was issued in Australia dealing with the use of sulphonamides in surgical practice. In this the principles laid down were the rapid attainment of a high blood concentration, the maintenance of adequate concentration during each twenty-four hours, and administration by mouth

where possible. A single course of treatment did not exceed ten days, and a leucocyte count was advised before another course was begun. The usual fluids and alkalies were given during a course, and close observation was made of the urinary excretion, and of any urinary abnormality or vesical symptoms. The dosage recommended was two grammes at once followed by one gramme every four hours, up to a permissible total of 35 grammes. The drugs available at first were sulphanilamide and sulphapyridine, and a little later sulphathiazole was also obtainable. Sulphanilamide was more used than other preparations during the early campaigns because of supply difficulties. The distances to be covered in the desert in transporting wounded were in part responsible for the introduction of greater elasticity in the interval between doses of sulphonamides. Backed by some experimental work, as told in the section on chemotherapy, the Australian surgical services found that large doses given twice or even once in twenty-four hours afforded an adequate blood concentration to ensure therapeutic result. In countries where the evacuation route was often long in both time and distance this was a significant contribution to the practice of sulphonamide prophylaxis of wounds. Further developments in chemotherapy will be described later. Other factors in the treatment of battle wounds in a forward area such as anaesthesia and resuscitation may be left also to later sections.

In more settled areas more deliberate surgery was undertaken. Types of wounds varied somewhat in different campaigns. In the desert, grenades, land mines and booby traps were responsible for multiple wounds in which many fragments were embedded. The cleansing of such wounds was sometimes a long and difficult task, especially in parts such as the buttock where deep injuries were inflicted on soft parts. Excision and plaster casing suited these injuries well. Secondary haemorrhage was sometimes a worrying complication, though it was rare in amputation stumps. It was dealt with where possible by seeking the vessel in the wound, but in certain sites, such as deep in the palm, between the leg bones, in the buttock, or in some parts of the neck this was not always possible. Due consideration was of course paid to collateral supply, and vessels whose ligation was known to be dangerous, such as the popliteal or the common femoral, were avoided. Direct control of a bleeding vessel in a wound was preferable to more remote control because of the already existing trauma. In a few instances gangrene necessitated amputation of a limb.

In hospitals where saline baths were available this method gave some excellent results with large wounds of soft tissues. After the bath a light sprinkling of sulphanilamide was applied, and dressings of *tulle gras*; skin grafting was used as early as possible. The bath method was found particularly useful in the treatment of severe burns. Wounds of regions in which "specialists" usually hold the field received only emergency treatment in forward areas, unless the clinical signs were such as to make further early action imperative.

Infections of wounds varied with the terrain. In Libya and Cyrenaica there was a curious contrast between the ease with which superficial

wounds healed and the indolence of the ulcers of the skin which were common in most parts of the Middle East. The rarity of gas gangrene has been commented on above. Gas infection occasionally occurred, apart from gangrene; the clinical distinction was a most important one, both statistically and prognostically. The former required only local treatment. Gas-forming organisms were found afterwards to be of much greater surgical importance in New Guinea. Though anaerobic bacteria were common in the Middle East, their virulence did not appear to be high. In any case infection of wounds was not a serious problem in the Western Desert.

Captured Italian prisoners were sometimes found to have wounds healing well, though they had received only rudimentary attention. The ready availability of skilled surgery was certainly an important factor in prevention. This provided good drainage and ensured that the effects of anoxia of tissues were minimised by the encouragement of good blood supply and the avoidance of inflammatory oedema with its destructive pressure. The manoeuvre of splitting deep fascia, for example, had prophylactic value, and helped to discourage an environment favourable to anaerobes.

C. diphtheriae was an occasional infector of wounds, though more often seen in septic ulcers. A grey or greyish yellow slough on the wound appeared, due to a thin layer of necrotic tissue, which spread at the edges. The occurrence of several small outbreaks of diphtheria in the Middle East forces emphasised the need of remembering it.

In the forward areas the prophylactic value of sulphonamides was difficult to assess, owing to the variable conditions. In base areas more careful evaluation was possible. There was no doubt felt of the value of systemic administration. No accurately controlled assessment of the value of sulphonamides used locally or systemically could be made in the A.I.F., as special teams for investigation could not be spared. Statistics, dependent on variable conditions, were unreliable. In a base hospital where the powdered drug could be insufflated on to a granulating surface previously cleansed by saline baths, the disappearance of streptococci could be proved. In forward areas no such conditions could be secured and statistical results were correspondingly less reliable. Though selectively useful in local application, the same fallacy appeared as in 1914-1918 when too much was expected from antiseptics. Suppuration and infection in pockets of wounds defeated sulphonamides used locally. Septicaemia was not a menace in 1940-1941, and the knowledge that sulphonamides would control general streptococcal infection permitted wound excision to be carried out safely over a longer interval period.

No large scale cultural observations could be carried out on war wounds of the A.I.F. in the Middle East, but the prevalence of the haemolytic streptococcus was undoubted. The observations of Keogh and Freeman on "desert sores" confirmed this. Other common aerobic organisms played the part of secondary invaders, and as will be seen, gave trouble after the usual pathogens had been controlled by specific measures. The need for making routine anaerobic cultures of wounds did not arise in the Middle

East; they were only made as required. Surgeons thought that the universal use of sulphonamides had some action in preventing a greater incidence of anaerobic infections. Further information on bacteriological findings is given later.

Tetanus was practically banished from war surgery by immunisation. One soldier died from tetanus who had only one inoculation, and in the concluding stages of the war an occasional instance of localised tetanus was seen following a wound. In 1940 Middle East administrative instructions laid down that wounded men immunised with tetanus toxoid were to be given 3,000 units of antitetanic serum, and if they were found later not to have been immunised, doses of 1,000 units were to be repeated weekly for three weeks. A later technical instruction was issued in Australia enjoining the use of tetanus toxoid in a stimulating dose of 1 c.cm. as soon after wounding as possible, instead of antiserum. Medical officers checked the records of immunising injections in each man's paybook: if the records showed incomplete immunisation or were missing, prophylactic antitoxin was given. Regular "refresher" injections of toxoid were given as a routine at yearly intervals to all servicemen and women.

The constitutional effects of serious wounds early aroused attention. For many years, especially in the pre-Listerian days when chronic sepsis was common, the evil effects of localised infection on the whole body had been recognised. More recent studies emphasised the importance of maintaining correct levels of red blood cells, haemoglobin and plasma proteins, and the supply of the correct aminoacids and vitamins in the diet. During the 1939-1945 period these aspects of the care of wounded men were well studied, and as time went on it was found that even in these days of aseptic surgery and the use of specific drugs, chronic infections of wounds had not been banished, and still had to be treated. Before penicillin was available organisms not controlled by sulphonamides and other measures could cause overt or covert sepsis which severely drained the blood and other tissues of the necessities for full living. At a meeting of surgeons in Egypt in 1942 the loss of protein due to large infected wounds was discussed, and attention was called to the need for seeking local abscesses, and effecting drainage in such conditions. Emphasis was placed on the value of a high protein diet containing in particular adequate vitamin *C*. Further reference will be made to these constitutional effects of wounds.

The influence of surgical specialties in base areas helped to effect striking improvements in wound treatment. The work of high grade general surgeons and others specially trained in plastic surgery, orthopaedics, thoracic surgery, and ophthalmology not only raised the standard of work in field hospitals to a high level but reflected on the methods used in forward areas. The influence of plastic surgery on traumatic surgery in general was great, and insistence upon the ideal of rapid physiological restoration of a sick or wounded man encouraged the early application of physical and occupational therapy.

All the advances brought by these and other applications of continuous study were potent factors in accelerating and improving the healing of war wounds.

WOUND TREATMENT IN THE PACIFIC CAMPAIGNS

When the Middle East chapter closed for the A.I.F. in 1942 with the return to Australia of the 9th Division, new problems arose. The Pacific Islands presented great difficulties of terrain and transport, of climate and of endemic disease. During these later years the importance of maintaining the surgical principles already laid down was emphasised. For example, in some of the forward posts in New Guinea, such as Myola, during the first New Guinea campaign men sometimes arrived as late as two days after being wounded. This was later duplicated in other areas. Oedema of muscle in the limbs had by that time resulted in plugging of the wound in the deep fascia, and adequate excision or incision was necessary in order to allow drainage. After some of these earlier New Guinea campaigns Brigadier Hailes, Director of Surgery, found it necessary to issue the following Technical Instruction, No. 81, which drew the attention of medical officers once more to the importance of adequate early surgical measures.

"Surgery in Forward Areas in Recent Operations.

"The standard of surgical work both in regard to the quality of the surgery and the condition of the wounded on arrival at Australian General Hospitals is generally satisfactory, but it was noticeable that excision of the wounds had been neither as extensive nor complete as in former campaigns. As a consequence suppuration under the ensheathing fascia and secondary haemorrhage were more troublesome.

"The attention of all surgeons operating in forward areas is drawn to the fact that, although there is every reason to be conservative over the amount of skin removed, the wounds will be laid widely open and extensively excised. The incision and excision of the ensheathing fascia and lacerated muscle will be maximal.

"The excision of the wounds should be cone-shaped with the base of the cone at the wound of entry, and also at that of exit if one is present, and the apex at the site of fracture or location of the foreign body. This will allow for adequate drainage and prevent a bottle neck obstruction. This is often the result of swollen damaged muscle blocking the track or the exit through a small opening in the deep fascia. To achieve this the fascia can be divided across as well as incised in the length of the limb, or a segment comparable to the base of the cone referred to above can be excised; this applies to the deep fascia throughout the body and nowhere more so than to the fascia of the thigh.

"A compound fracture of the thigh is not adequately excised unless the site of the fracture can be readily visualised from the wound of entry in the case of a penetrating wound and from both the wounds of entry and exit in the case of perforating injuries.

"All wounds will be left widely open. No sutures will be used.

"It is realised that this wide excision is contrary to the practice in some theatres of operation as judged by articles in the current medical press.

"In the operational area in and around Australia wide excision and not conservation will be the routine. In the case of uncomplicated soft tissues injuries from rifle bullets the surgeon must use his own judgment. If the exit wound is large the wounds will be excised. If a bone is fractured the wound or wounds will be excised.

"Except in the case of very small and multiple wounds and some thoracic injuries all penetrating and perforating wounds of soft tissue inflicted by any missile, other

than certain wounds due to rifle bullets, will invariably be excised. If the case is seen too late for a stereotyped excision it will be treated by ample incision and excision of sufficient pulped fascia and muscle to allow for adequate drainage. Buttock wounds are particularly dangerous; all such will be opened widely and extensively excised; no sutures will be inserted."

Colonel C. W. B. Littlejohn, Consulting Surgeon in the area, found that more radical excision was often necessary. It must be remembered of course that in a long war with expanding forces large numbers of new medical officers come to duties in some ways strange to them, and others take up responsible positions with little more than civilian experience behind them. Continual vigilance was necessary. Some new problems appeared. For instance, *Salmonella* infections were not uncommon in the islands, and one of these due to *S. enteritidis,* was sometimes associated with metastatic suppuration. Abscess formation in soft tissues or in bone was occasionally seen in forward areas due to this cause.

Streptococcal infection had been important in the Middle East, but with the move of battle fronts to the Pacific Islands staphylococcal infection was more common and troublesome. The type found was the haemolytic *Staphylococcus aureus* coagulase positive. Where both streptococci and staphylococci were present in a wound the latter were not readily disposed of until penicillin became available. The different roles of these organisms were illustrated by a few examples of symbiotic bacterial gangrene which occurred in army practice. N. J. Bonnin reported one instance of this condition after operation for empyema. The usual characters of this gangrenous ulcerative lesion were exhibited; wide excision with skin grafting effected a cure. The streptococcus in this symbiotic partnership was eradicated, but the staphylococcus persisted in the empyema wound after the skin ulceration was healed, even though penicillin was obtained for use in the later stages. Another type of ulcerative lesion was seen and described by K. W. Starr in which a micro-aerophilic streptococcus caused extensive ulceration and invasion of the scalp and outer table of the skull. Lacking the symbiotic effect of the staphylococcus, the lesion was not associated with gangrene, and repeated excision and dermatome skin grafting eventually gave a good result.

In the Pacific campaigns as in those in the Middle East no large scale investigations were made in the bacteriology of war wounds, but the predominance of the staphylococcus over the streptococcus was evident. Late in 1943 Perry examined 226 unselected war wounds in the Moresby area, and isolated *Staphylococcus aureus* 137 times (61 per cent) and *Streptococcus haemolyticus* only 30 times (13 per cent). Certainly respiratory infections were not common in the islands, and the routine use of sulphonamides in the wounded probably had an individual and a mass effect in lessening the incidence of streptococcal invasion. Secondary invaders did not seem to be so important at that time, but Perry found *B. proteus* 50 times (22 per cent), *Ps. pyocyanea* 19 times (8 per cent) and coliform organisms 27 times (12 per cent). In the later years when sulphonamides and penicillin accounted for the Gram-positive bacteria the

Gram-negative varieties became significant, and even if not initially present, often appeared. In New Guinea the staphylococcal infections were more serious and important than the streptococcal. Thus, in one hospital in a period of nearly a year no streptococcal blood infections occurred, but four staphylococcal general infections were seen. In this series about 35 per cent of the organisms found in wounds were *Staphylococcus aureus,* and 20 per cent *B. proteus,* while haemolytic streptococci made up only 7 per cent and were thought to be secondary invaders, like proteus, the coliform group and pyocyaneus.

Anaerobic bacteria in wounds in the islands were also found to differ from those found in the Middle East. The notes published in England in 1940 by a committee representing the Medical Research Council and the London Sector Pathologists gave information concerning the cultural and other properties of the clostridia. In this pamphlet the predominance of *Cl. welchii* during the 1914-1918 war was emphasised, and this was expected also in the Middle East. However, Major McLennan, R.A.M.C., found that in anaerobic infections among members of the British forces in that area *Cl. oedematiens* was the commonest type, with only small numbers of *Cl. septique* and *welchii.* It was fortunate that these infections were rare in that theatre of war, for the effect of sulphonamides on *oedematiens* was slight, and a specific antiserum acting on this organism and its toxin was not readily obtained owing to the small demand, and to its rarity. The only measures left were local excision, of undoubted value, X-radiation also of value, and amputation. Practically all fatalities were due to *oedematiens,* which had a troublesome feature of later sporing in the tissues, causing a severe exacerbation after two or three weeks. Anaerobic infections were much commoner in New Guinea, though even here they were not statistically formidable.

Anaerobic cultures were not found a necessary routine in the Middle East, and in New Guinea they were not commonly attempted at field hospitals. Little more could usually be done than to demonstrate the presence or absence of the most easily identified pathogen, *Cl. welchii* by the characteristic reaction in litmus milk.

During the early stages of the Kokoda trail fighting, cultures from 29 grossly infected wounds were sent to Melbourne, where they were investigated by Dr A. W. Turner of the Council for Scientific and Industrial Research. He found *Cl. welchii* 8 times, *Cl. septique* 5 times, *oedematiens* 7 times, *sporogenes* 9 times and *bifermentans* 10 times, and on every occasion also some unidentifiable though apparently pathogenic clostridia. Only three of these patients died. Later, at the end of 1943 Captain Perry found that from his 226 cultures *Clostridia welchii* were isolated only twice and unidentified varieties a few times. The latter series was taken from wounds already submitted to thorough treatment in forward units, whereas the former came from wounds of men debilitated by hardship received practically direct from the front line. The frequency of the various varieties of clostridia in New Guinea conformed more to the usual findings in previous military actions, though it appeared that not all the

gas-forming organisms met there were virulent. At the 2/9th Australian General Hospital in the Upper Moresby area 100 men with anaerobic infections were admitted in four months of active campaigning. Many of these infections were mild but some were severe. Serum was used for definite clinical infections, the dosage being 30,000 to 60,000 units, but surgical measures with blood transfusion and sulphonamides were thought to be more important aids to recovery. Of course there were many factors of difference touching the nutrition of the men, the facilities for surgical treatment and for evacuation along the line of communication, as well as those concerning the local terrain. The distinction between the presence of gas-forming organisms in wounds and the presence of active gas gangrene infections is most important. The British report mentioned above summarised well the clinical features of frank infection, and pointed out that gas gangrene is a clinical concept. In this and other writings and instructions clear pictures of the clinical state were drawn. Local signs such as swelling and crepitation were suggestive, so too were the signs of general toxaemia, which sometimes reached a serious climax very swiftly. The tendency of the condition to invade single muscles or groups of muscles was characteristic, and helped the carrying out of radical excision of infected tissue. This could be recognised before the later stages of frank gangrene by the brick-red colour of the muscles which were non-contractile and did not bleed when cut. It also sometimes invaded areolar tissue, particularly where effusion of blood had occurred

Such information was widely diffused, and measures taken to follow up the results of front line work. Thus the efficacy of single measures to counter anaerobic tissue infection cannot be assessed. No doubt the small incidence of gas gangrene in wounded Australian soldiers was largely due to prompt recognition and adequate surgical excision, relief of tension and drainage, without which chemotherapy and passive immunisation would probably have been in vain.

Before the war W. J. Penfold and Jean C. Tolhurst had investigated strains of *Cl. welchii* isolated from civilian patients, and produced formol-toxoids which produced active immunity in animals. It was hoped at the time to apply this to human prophylaxis, but this was not done. The matter was well discussed in 1940, but it was felt by a panel of hygienists and bacteriologists that the evidence and the need were alike slender at the time. Combined toxoids of tetanus and gas gangrene were investigated experimentally, but no action was taken. Fortunately the rarity of gas gangrene justified this opinion.

During the first campaign on the Owen Stanleys the difference made by the terrain was apparent in the incidence of wound infections. During the first phase, before a practicable airstrip was captured from the Japanese, the conditions were difficult and practically all supplies were very scanty, but the climate on the ranges was cool and insects and pathogenic bacteria were almost absent. All wounded men received 6 grammes of sulphanilamide on the first day and 4 grammes each day thereafter for seven days. The sick and wounded had to walk over the ranges, or

be carried on stretchers by native bearers or be held in the field ambulances till well enough to move. During the next phase, airfields were soon available at Kokoda and on the coastal strip to the north of the mountains. Surgical teams, attached to the main dressing stations, were again used. Adequate excision of wounds was here necessary on account of the prevalence of infections. One obvious difference in the wounded in New Guinea to those treated originally in Libya was their long clothing, muddy and sodden, a contrast to the relatively clean and often brief garments of the desert. The extra time involved in removing this and in washing the wounded men added to the strain on the staff of forward surgical posts. Anaerobic infections were not infrequent, the commonest organisms being *welchii, oedematiens* and *septique* in a ratio of about 3:4:5. The contrast with the findings in the Middle East will be noted. In the last phase of this campaign the fighting was in shocking country, with patches of tall kunai grass interspersed with thick jungle and mud everywhere kept liquid by the constant rain. Air transport, weather permitting, lifted the wounded over to Moresby, but as this was not always reliable, it was fortunate that the use of sulphanilamide extended the safe period for wound excision to three days, as will shortly be told. Though over 100 cases of anaerobic infection were seen here, it appears that most of these were saprophytic in type. A few rapidly fatal infections were seen of *oedematiens* type, in the opinion of the Surgical Consultant, Colonel C. W. B. Littlejohn.

In spite of the unpromising conditions in New Guinea, where actions were fought both in mountainous country and in hot humid swamps and jungle, experience proved that the safe period for excision of wounds could be extended. The advisable limit of time between the wounding of a soldier and his submission to surgical treatment was previously placed at eighteen hours. This time interval was gradually lengthened, and after the first campaigns in New Guinea it was proved that wounds could be excised as late as seventy-two hours after their infliction. Technical Instruction No. 51 pointed out that this delay was not only safely possible, but essential, owing to the prevailing conditions of terrain and transport. Emphasis was again placed on the removal of devitalised tissue so as to permit efficient drainage, and minimise the strangling effect of inflammatory oedema. The value of wide incision of wounds was also stressed. Shell dressings were found convenient for application to wounds after surgical treatment; they were sterile and comfortable. Gloves were not always used for minor wounds in all forward posts, but always for major procedures. Undue sweating of the hands in gloves was often troublesome. Laundering of gowns was often difficult: this alone with other maintenance work often occupied the time of one orderly. Where gowns could be dispensed with the surgeon's costume often consisted of trousers, gaiters, boots, cap, mask and apron, a gown being donned when required. Operation sheets after being washed and soaked in "Dettol" or similar antiseptic could be used moist in this climate without additional discomfort. Where sterile drums were available these were of the greatest value, as individual gear remained ready sterilised till the moment it was needed. The oral

administration of sulphanilamide to wounded men was rigidly enforced. It was found that medical officers working with surgical teams could use considerable influence with the soldiers to ensure that they took the tablets at regular intervals, as these sometimes had to be entrusted to the men themselves during their movement to base. So firm was the belief of many wounded men in the efficacy of this treatment that they relinquished the remaining doses to nurses in hospital with great reluctance. The administrative details of siting forward posts, surgical teams, and field medical units rather belong to the operational part of this history, but it is desirable here to point out how radically the battle zones of New Guinea differed from those in which Australian troops had their first experiences in this war.

Technically the surgical problems could not always be answered in the same way. The mobility of desert warfare in which even the main dressing station of a field ambulance with an attached surgical team was fifty miles from the fighting, was replaced by a relative lack of movement in an area where most things had to be carried or dropped from the air, and the line of communication was often tenuous and uncertain. The siting of a surgical post therefore depended not on the level of the unit to which it was attached but was decided by a combination of logistics and pathology.

In some of the later island campaigns it was not practicable to transport wounded to settled areas within the interval of time before operation just mentioned. Extemporised surgical posts had to deal with the wounded early, and forward units had to hold them for a time till their movement was surgically safe. This applied particularly to emergency conditions, abdominal wounds, and compound fractures of the long bones. Operations were often performed under extemporised shelters by day and under blacked-out conditions of intense discomfort by night. The surgeon sometimes stood perforce in mud while operating. Compound fractures have been dealt with at night with no other light than a small headlamp and a pocket torch. On the Owen Stanley Ranges and other mountainous parts a problem was to protect patients from bitter cold and rain: on the soaked muddy levels of the coastal strips the intense humid heat produced entirely different hazards. Patients with fractured femurs whom the surgeons expected to return to base by air could not always have weight traction applied, as they might be called for at any time should planes land in the vicinity. This element of unpredictable evacuation was a special difficulty during part of the first New Guinea campaign. In amphibious landings treatment might be undertaken in a beach unit, or on a landing craft or a larger vessel. These diverse conditions all imposed on the surgeons limitations of their own peculiar type, and comparisons of methods and results in such circumstances can hardly be fairly made.

Many patients were transported on native-made stretchers carried by a team of native carriers. As the natives rested the poles on their shoulders the transverse space in the stretcher was limited, and patients with injuries of the thorax or long bones were apt to suffer from compression by the poles.

In certain areas infection was more common, and, as already remarked, gas gangrene was a definite risk. Yet careful technique and rigid instruction and supervision of orderlies assured satisfactory conditions of asepsis.

In the island campaigns a large proportion of the wounds treated involved the upper and lower extremities. Seventy-five per cent was a common proportion of these injuries to the total, and about half of these were complicated by compound fracture. Wounds fell mainly into two classes, those due to gunshot wounds and a larger proportion caused by fragments of grenades, shells and mortars, the latter being commoner. Deaths were usually due to severe and complicated injuries often involving large areas of soft tissue and viscera in one or more of the body cavities. Bullet wounds inflicted by the small .273 calibre Japanese bullet often did little harm unless they struck bone and caused shattering or damaged a large blood vessel. It was possible for a blood vessel to be endangered without much, if any, external sign.

Sword wounds were also seen, usually on the head or shoulder, and often of tangential nature. Occasionally lesions of the brachial plexus were produced by indirect violence.

By the time the Salamaua campaign was fought in 1943, it became evident that one of the most important tasks of a field ambulance in jungle warfare was the building of medical posts and other shelters. Experimentation proceeded in the best methods by which the "bush carpenters" of the unit could provide adequate shelter and a well lit operating theatre capable of being blacked out at night, and mark tracks for night traffic. On the coastal plains an overhead shelter alone was sometimes used in emergency even for operating: this was possible because the almost constant rain at least fell vertically. Some training was necessary too in minor infantry tactics and in defence against hostile patrols and shell-mortar fire. It will be seen that even though the conditions under which forward surgery was done were more static than in flat extensive battlefields like the desert, they imposed singular difficulties and hazards. As many patients in this and similar campaigns were transported by small sea craft their comfort and protection against weather were important considerations in their after care. Similar precautions were necessary where jeep ambulances were used, which were jeeps with double-decker stretcher racks. Further details will be given in following sections of the work in various branches of surgery. One complication of all varieties of forward surgery deserves special mention here, malaria. Severe malaria was not well tolerated by the severely wounded, especially under the unfavourable climatic conditions. Quinine was given by the intravenous route practically as a routine to all seriously wounded men, and to all with abdominal wounds in some of the heavily endemic areas. Blood for transfusion was not easy to get in forward posts; though it was sent by air from the mainland, unavoidable delays occurred in its ultimate distribution to distant points in difficult country. As a result of various unfavourable factors the recovery rates were lower in some areas. In the battle for Salamaua even careful following of the technique established for abdominal surgery in

the Middle East could not produce better than about 33 per cent recoveries. It must be remembered too that the time elapsing before operation was sometimes much greater than the average in the Alamein battle. The mere necessity for holding patients for even a short period in some of these areas which were exposed to air raids imposed conditions of hardship on sick men. In the later stages of some of these operations the conditions were very different, with greater security of comfort, and the boon of air transport. Mere figures of results cannot express the difficulty or the value of the work done by some of the surgical teams.

In the later phases when assaults were made on Japanese held areas in Borneo ascendency had been established by sea and air, and the operations proceeded smoothly. Controlled landings, early setting-up of well equipped units, freedom from serious external attack, and adequate and prompt evacuation of wounded by sea allowed surgical teams and staffs in forward and semi-forward units to work under favourable conditions. Operating facilities were also available afloat in some instances. These advantages were exploited to the full and the results were very satisfactory. Full supplies of penicillin had by that time made a vast difference in the surgical prevention and control of infection, both in the sea-borne forces engaged in these operations and in the forward base established at Morotai. The story of the influence of antibiotic therapy is best left to a separate section, but it may be anticipated by pointing out that before the introduction of penicillin no one could have dreamed of the possibility of wounds being under control before arrival of the wounded at a forward base, or of compound fractures of long bones being immobilised there by open operation and plating.

In general surgeons have shown that they have amply earned the right to use every scientific advance that the military situation can permit for the practice of their art. In the Australian forces surgeons have shown both their readiness to meet the limitations of circumstance half way, and their ability to give their patients the full benefits of refined techniques wherever this is safely possible.

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CHAPTER 32

CHEMOTHERAPY

AT the outset it is important to realise that the introduction and refinement of chemical or biological methods of limiting the development of bacteria in wounds must not be regarded *per se* as a revolution. It is easy to say that penicillin has revolutionised certain forms of treatment; in some respects it has, but it is more correct to say that it has permitted a closer approximation to certain surgical ideals, and has helped strict adherence to surgical principles to win greater rewards.

SULPHONAMIDES

The introduction of powerful and not over-toxic members of the sulphonamide group of drugs into clinical medicine and surgery has achieved a great measure of control over certain types of infection, all the more significant because of its biological basis. The history of the war years shows how the older concept of antiseptics continued to influence the local use of sulphonamides for some time, but the risks and drawbacks became more evident, and this method used with greater reserve. As early as January 1941 there were reasons for caution in ascribing much of the good condition of wounds to sulphonamides. In the relatively clean, though dusty, desert air the Italian prisoners' wounds healed as well as those of the British and Australian soldiers, in spite of the drawback of military misfortunes which caused the Italians to flock into prisoners' cages with wounds unsutured and untreated save for first aid dressings. It is of interest to note that wounds of both parties were not sutured. This warned against undue enthusiasm for sulphonamides as a panacea. In June 1941 Colonel Hailes reported to Major-General Burston that the value of these drugs was hard to assess, but appeared to be great when they were given by mouth, whereas their value locally was doubtful. On granulating surfaces streptococcal infection disappeared. As described in the previous section, 0.5 gramme of sulphanilamide was given two hours after treatment of a wound, and repeated four hourly for four days, the dose being doubled for two days if frank infection existed.

During the operations in North Africa in which the 9th Australian Division was engaged, 5 tablets of 0.5 gramme were given twice daily for four days or until the wound was considered to be controlled. Keogh, Wood and Andrew of the 2/2nd Australian General Hospital previously carried out some observations on the blood concentration maintained by twelve hourly dosage of sulphapyridine, and found that this was adequate. They pointed out that the dose interval was relatively unimportant: more essential was the correct selection of patients, and the use of sufficient dosage for a sufficient time. The clinical results were consistent with this finding. Anaerobic streptococci were found at this time as occasional invaders of muscles causing oedema and gas formation not due to

clostridia. Infections due to haemolytic streptococci of the Lancefield group A were found to be controlled well by sulphanilamide. The collective opinion of medical officers doing surgical work was illustrated in a clinical meeting in a medical unit of the A.I.F. in Tripoli in Syria in December 1941 when a recommendation was made that a check on the administration of sulphonamides to wounded should be routinely made by a medical officer, for example a member of the staff of a motor ambulance convoy. The local use of sulphanilamide was still found of value when it was correctly applied: a dusting of powder following excision of a wound, and then "Vaseline" gauze was used in much of the surgical work incident to the battle of El Alamein. Occasionally mistaken zeal led less experienced medical officers into the error of incorporating a quantity of sulphanilamide in a tight packing. Due warnings were circulated against this error. When part of the 2/5th A.G.H. remained in Greece to serve the British and Australian prisoners of war a great deal of advanced sepsis was encountered in wounded men who had suffered delay and unavoidable neglect before their admission. Sulphanilamide was thought to diminish sepsis somewhat, though the impression was gained that secondary haemorrhage was rather more frequent in men whose wounds were so treated. Sulphanilamide and *Prontosil album* were both used, being obtained from the Germans.

As pointed out previously, sulphanilamide was used exclusively for local application, and usually for internal dosage—the only other drugs of the group that were available was sulphapyridine, which had its drawbacks in causing nausea and vomiting, and sulphathiazole in very limited quantities. Sulphanilamide in saline solution was available in "Soluvacs" too, and was sometimes used in base areas where the administration could be advantageously combined with fluid replacement. In New Guinea when the permissible period for the performance of wound excision was extended to three days this was regarded as an expression of confidence in the routine of non-suture and the giving of sulphanilamide by mouth. The routine of oral administration of sulphonamides as a prophylactic against wound infection was continued through the later war years.

In 1944 surgical opinion as expressed to the advanced medical headquarters at Morotai cast doubt on the value of skin antiseptics, and pronounced the systemic and local use of sulphonamides according to the prescribed indications to be much more powerful as a prophylactic against established infection. Further details of their local use in wounds of special regions are given in the appropriate sections.

With the greater frequency of skin infections in the Pacific Islands more sulphonamides were exhibited as local applications, with the natural results that more local irritation, and more sensitisation appeared. Attention was drawn to this risk in a special instruction, which pointed out the danger of producing severe general reactions by the administration of a sulphonamide to a previously sensitised patient. The only correct indication for the use of sulphonamides in septic sores was laid down as being the demonstration of haemolytic streptococci. A warning was also given of

the irritant nature of sulphathiazole on the cerebral cortex, and an instruction was issued on the subject. If a sulphonamide was to be used locally in cranial surgery a non-epileptogenous drug such as sulphapyridine or sulphadiazine was recommended.

Technical difficulties arose in the sterilisation of sulphanilamide powder, which, when treated by heat in an autoclave, became granular and difficult to apply by insufflation. This was overcome by adding 2 per cent bismuth carbonate or 5 per cent kaolin. The latter was preferred especially when multiple applications were used, owing to a certain risk of metallic poisoning by bismuth. All hospitals and clearing stations were positively directed to ensure that the powder used for wounds was sterilised. It was found that repetition of the sterilisation was impracticable, as it altered the physical properties of the powder.

In 1944 when the manufacture of sulphamerazine began in Australia it practically replaced sulphadiazine and sulphathiazole in service hospitals, as both of these drugs had to be imported. Sulphapyridine and sulphanilamide were still freely obtainable and the latter was still recommended for use wherever it was suitable. Sulphamerazine, the monomethyl derivative of sulphadiazine, had the advantage of being more soluble than sulphadiazine, but the possibility of renal block, though small, was not negligible, as experience later showed. Nausea and vomiting only occasionally occurred, and a few instances of toxic effects on the bone marrow were seen. The toxic symptoms of sulphamerazine were of course those of the sulphonamide group in general, excepting in some respects the original sulphanilamide. In hot climates the risk of renal block was always to be thought of particularly in patients who had suffered severe loss of fluid. The rapid absorption and slow rate of excretion of this drug assured high blood levels with reasonable doses, and dosage was therefore necessary only twice a day. In a technical instruction two dosage rates were suggested, one high and the other medium, the former having 8 grammes and the latter 6 grammes as an initial dose. The doses used thereafter were respectively 4 grammes and 3 grammes twice daily for a day, 4 and 2 grammes twice daily for two days, 2 and 1 grammes twice daily for one day, and then a maintenance dose of 2 grammes or 1 gramme if required. The higher dosage rate was not often found necessary, and except for severe meningeal or pulmonary infections or fulminating streptococcal infections, the lesser dosage was preferable and sufficient.

The combined use of sulphonamide and penicillin powder will be mentioned in connection with penicillin and its surgical indications.

An important point in connection with the value of sulphonamides in the treatment of wounds is of course the nature and types of the infecting bacteria. In 1940-1941 streptococcal infection was important in England, and was said to be the dominant invader in 50 to 75 per cent of wounds. In the Middle East the streptococcus was also a very common infective agent, and the terrain on which most of the battles were fought was favourable from the point of view of infection. In general the success of sulphonamides owed something to these factors, though it seems fair to

admit that septicaemic infections by streptococci were prevented to a considerable extent by the oral and parenteral use of these drugs. The routine of limiting the period of administration obviated serious toxic effects. The danger that the blood concentration might attain a high level by concentration from a large surface, such as from burns, was realised. Later on in New Guinea, as pointed out above, the staphylococcus assumed a much more important role.

Whether sulphonamides prevented gas gangrene to an appreciable extent or not is debatable. The general excellence of forward surgery in the isiand battle zone must be given due praise. Prompt and wise excision of infected and potentially infected tissue was probably of much greater importance in the treatment of wounds received in the contaminated mud of some of these areas. The choice of the individual sulphonamide drug was important too. The members of the series differ in their persistence in a wound, sulphanilamide being only briefly persistent. Sulphanilamide also had the drawback of being easily countered by the presence of para-aminobenzoic acid in pus and other degenerate tissue. On the other hand it was readily soluble and relatively unirritating.

ACRIDINE ANTISEPTICS

Before dealing with the vast changes brought by penicillin in war surgery it is well to consider the part played by antiseptics. The clinical use of the aminoacridines for their antibacterial properties earned these preparations a good reputation in the latter part of the 1914-1918 war. After this, disillusionment dimmed their value in civil practice. It seemed unlikely that any substance could antagonise bacteria without damaging the tissues of a wound, despite the undiminished potency of the aminoacridines in the presence of blood serum. The introduction of sulphanilamides stimulated further work on these dye derivatives, and greater understanding of the best methods of employing them led to better results.

Australian surgeons were greatly helped by the work of Adrien Albert on the aminoacridines. Albert has pointed out that it may seem curious at first that these antiseptics have retained an important place in surgical practice, since they need more caution in their local application than sulphonamides or penicillin. The latter, however, have wider use when administered internally, owing to the real risk of producing resistant bacterial strains, and sensitivity in the host. The selectivity of sulphonamides and penicillin and their activity against Gram-positive bacteria have thrown into some relief the importance of the Gram-negative invaders of wounds.

The lethal qualities of acridines against most of the organisms commonly found in wounds (except *Pseudomonas pyocyanea*) and the ease with which they can be sterilised by heat without loss of potency have increased their value. In addition they rarely induce drug-sensitivity, and are not neutralised by para-aminobenzoic acid. Some of the newer acridines, such as "Monacrin" (5-aminoacridine hydrochloride) have proved of undoubted value. "Monacrin" after satisfactory laboratory trials

in 1942 was submitted to clinical trial in 1943. Some of the reports from the 115th Military Hospital, Heidelberg, and the 2/4th A.G.H. were not very satisfactory in 1943, but later Poate reported a series of 24 patients with long-standing septic wounds involving the long bones. One in one thousand aqueous solution of "Monacrin" was run into the wounds through Carrel tubes for four hours per day, dressings being changed every fourth day. When healing began, an emulsion of oil, calcium hydroxide and water containing 20 per cent of one in four hundred "Monacrin" was applied and later a greaseless ointment. A mixture of "Monacrin" one part to forty parts of sulphanilamide was recommended by Poate as a preparatory application for facio-maxillary wounds being subjected to plastic procedures. By this means sulphonamide-resistant organisms were removed from granulating surfaces. Recent wounds were successfully treated with "Monacrin" 1 in 100 sulphanilamide powder after *débridement,* and primary suture was accomplished without complication. Turnbull as described later, also found aminoacridine hydrochloride valuable in sepsis of long bones.

Experience showed that the effect of the undiluted powdered drug was too necrotic on tissue for its use on more than the first occasion. Poate and Turnbull found proflavine and 2:7 diaminoacridine useful, but 5-aminoacridine gave better results. Other clinical results since, such as those of Arden and Starr have shown that the newer acridines have a place in traumatic surgery.

"Neo Monacrin", 5-amino-1-methyl acridine was produced too late to be available for extended trial during the war, but its greater solubility, enabling it to be used in isotonic solutions and its slightly greater potency and reduced toxicity suggested that it should be valuable. One useful property of "Monacrin" was pointed out by Albert. Though absorbed by surgical gauze it was not fixed thereto, and was still available for solution in the body fluids. Proflavine was also the subject of research. The water-insoluble form has been found damaging to tissue, hence the neutral sulphate (proflavine hemisulphate) is preferable. The objections to the acidic nature of proflavine were pointed out by Albert and Gledhill in 1943, and were removed by the boiling of the acid sulphate with sodium bicarbonate, a neutral solution thus being made.

It will be evident from considering the experiences and views of different surgeons as to the value of chemical substances in controlling septic infections of wounds, that such views to be of value must rest on a sound basis. This is particularly the case with antiseptics applied locally. B. K. Rank, basing his views on some years of experience in handling surface wounds in patients subjected to reparative surgery, pointed out that there are four requisites to be fulfilled before a wound can be considered suitable for local antiseptics. These are as follows: (1) there must be no spreading tissue infection in relation to the wound, (2) the drug must have access to the whole of the wound, (3) there should be no focus of repeated reinfection of the surface of the wound, and (4) the nature of the bacteria infecting the wound must be known. The question of reinfection is par-

ticularly important, since this may arise from retained foreign bodies or from sepsis of bones. There is, too, the important matter of producing bacterial resistance, which may arise if an antiseptic is persistently used under unsuitable conditions.

The nature of the infecting organisms must be known if the correct antiseptic is to be chosen. In assessing results of treatment of war wounds, these factors must be considered, and, as pointed out already, no evaluation can be made unless surgical operative principles are correctly applied.

It is curious to reflect what an important division in bacteria was made when the peculiarities of Gram's stain were first demonstrated. Since so much fruitful research has begun from the physical and chemical properties of dyes it would seem that there may be important principles yet to be discovered related to this property of "Gram-positiveness". Further, as Rank showed, a chosen antiseptic must be used in correct fashion, and the most appropriate member of a group must be thoughtfully chosen. This has been pointed out in connection with the sulphonamides. It is also true with regard to the acridines. Albert's work indicated the structural and chemical properties of these drugs in relation to their therapeutic action, and a stimulus was given to their use by the fact that the work was carried out in Australia, and the drugs were thus readily available. Their solubility was an advantage, provided their damaging action on tissues in higher concentrations was remembered. Rank's experience showed that proflavine sulphate was more powerful in antiseptic action than the sulphonamides, but in concentrated form, like powder, it had a coagulant effect and lowered epithelial activity at the edge of the wound. Use of Albert's buffered solution gave satisfactory results, if continued for only limited periods up to five days. Wounds with predominantly staphylococcal infections responded well, so too did wounds infected by sulphonamide-resistant bacteria, and those inaccessible to insufflation. A technical instruction set out the properties described above, and advised that a solution of 1 in 1,000 proflavine and a powder containing 2 per cent proflavine and 98 per cent sulphanilamide were safe. "Monacrin" was found to be suitable also when used in 1-1,000 solution, and its favourable pH made buffering unnecessary. No definite evidence of any superior effect on Gram-negative organisms was found, and a similar experience was noted with 2-7 diaminoacridine (Diflavine). One drawback even with "Monacrin" was the occurrence of reactive changes in the wound after several days, making conditions less favourable for grafting.

In Heidelberg Military Hospital trial was also made of other antiseptics, such as "Propamidine", a member of the aromatic diamidines, and "Tyrothricin", one of the biological series. No special advantages were demonstrable with either, though Belisario found "Tyrothricin" useful for septic sores. It is probable that antibiotic drugs will replace substances such as the acridine group, but the latter have played a useful part. The prevalence of gram-negative bacteria in wounds previously infected by gram-positive organisms sets a problem which demands a biological answer: in this the acridines have already played a useful part.

PENICILLIN

Penicillin comes more aptly into a class of its own and will now be considered. Its extraordinary powers have perhaps obscured the lesser virtues of other antibacterial preparations, but it is still true that surgeons must be prepared to bring to bear on some of the problems of wound infection a lively interest in bacteriology, a flexibility of technical methods in the use of antiseptics, and a keen appreciation of their physical and chemical properties.

Following on the early field work on penicillin in 1943, this substance became available for trial in Australia early in 1944. In March 1944 the Director-General of Medical Services arranged for an investigation to be undertaken in Heidelberg Military Hospital at Melbourne. The clinical work was carried out by Majors R. Officer and J. Loewenthal and Captain J. W. Perry, laboratory collaboration being supplied by the Director of the Commonwealth Serum Laboratories where a special team led by Major P. L. Bazeley had successfully undertaken the production of penicillin. The discovery of penicillin is now a familiar story and need not be retold here, but it was a stimulus to the Australian medical services to have the advantage of a personal visit by the Australian Sir Howard Florey who was responsible for the clinical application of this antibiotic.

Penicillin was then being produced from cultures of the mould grown, harvested and purified by an extemporised plant devised by Bazeley and his colleagues after a visit to America where the early commercial production was being carried out. The first clinical trials in the Australian forces were made with the sodium salt and crude and refined preparations of the calcium salt. One hundred and forty-one patients were treated and the results studied. At that time penicillin was not as highly refined as later methods made possible, but doses up to 200,000 units per day were injected intramuscularly or intravenously, and up to 15,000 units intrathecally. Quantities up to 20,000 units were introduced into serous cavities without risk. Toxic effects were virtually absent. Only in a few instances was urticaria seen in this series. One patient had severe headache after each injection. No fever due to penicillin was encountered.

Due regard was paid to known differences in sensitiveness to penicillin of various types of bacteria. The importance of the production of penicillinase by certain organisms was also recognised. Standard strains of *Staphylococcus aureus* and a group A B-haemolytic streptococcus were used for assays of penicillin. The Oxford method and the serial dilution method were both used for the estimation of the penicillin content of fluids. The preparations used were solutions, powder and creams. The standard "Soluvac" saline solutions were found to have a pH ranging from 6-7 to 7-8, and the glucose solutions from 4-5. Up to 40 per cent penicillin was inactivated if kept in saline at these hydrogen ion concentrations for twelve hours at 24°C., and 60 per cent at 37°C., and up to 90 per cent in the case of glucose. The former were found a satisfactory medium under ordinary conditions of use. Solutions were only made in saline at 5°C.,

and diluted or otherwise dealt with at once. Intramuscular injection was usually employed, and continuous intravenous infusion in a few cases.

Powdered "crude" calcium penicillin was mixed with sulphanilamide, containing 5 per cent light magnesium oxide or finely ground human serum: 5,000 units of penicillin were present in each gramme of powder. The conditions treated included pneumonia, meningitis, local staphylococcal infections, osteomyelitis, renal tract infections, empyema, joint infections, eye and ear infections. One patient was treated for gas gangrene. Wounds of soft tissues with and without fractures of bones, burns and granulating wounds were also treated.

At that time dosage was not settled, but it was thought that an upper level of 100,000 to 200,000 units was sufficient in an adult, and that doses over this were wasteful. Intramuscular injections were given either in regular three hourly doses of 10,000 to 20,000 units or 10,000 to 15,000 units at 6, 7, 8, 9 and 10 o'clock morning and evening.

The investigating team published informatory clinical details of the patients and also laid down clear principles of treatment, epitomising the work then rapidly multiplying in different parts of the world. These were, in brief, that wherever possible the infective agent should be proved to be sensitive to penicillin, that the methods of administration be so devised as to ensure contact of the antibiotic with the organisms, that all dead tissues be removed and all abscesses drained, that in infections by exotoxin-producing bacteria the appropriate antitoxins be also given, and that care be taken to ensure continued potency of the penicillin. They emphasised the outstanding nature of the early symptomatic response of the patient to the treatment, and the rapid recovery in suitable cases of acute bacterial invasion. They also recognised the slower response in chronic infections and the tendency to recurrence. The final summing-up was a modest evaluation of this remarkable substance. "Used within its limitations, penicillin has proved to be a valuable therapeutic weapon." Conceived in a scientific spirit, based on closely collaborated laboratory work, and critically assessed, this early trial of penicillin in the Australian Army Medical Corps was praiseworthy for its care and its reserve.

As the output of penicillin in Australia increased it became possible to apply it much more widely, and to supply the civilian needs which soon became clamorous, but were administered with strict fairness. Army medical administrative and technical instructions stated that the drug was only available in limited quantities, and was controlled by D.G.M.S. on the mainland and by D.D.M.S. of New Guinea Force in New Guinea. At first it could only be issued to general hospitals, and then only for the treatment of staphylococcal septicaemia or pyaemia or streptococcal septicaemia which had resisted sulphonamide therapy, septic fractures or joint injuries with streptococcal or staphylococcal infection which, despite negative blood cultures, were not progressing satisfactorily, and other severe infections in which its use was sanctioned. Dosage of 120,000 units daily was suggested. Early in 1944 a trial was carried out in a forward area of the prophylactic value of penicillin in enabling primary

suture to be performed after excision and treatment with penicillin powder. Only a small number of wounds was treated at first. The results were very satisfactory, healing by first intention being obtained in nearly every instance. In a base area patients with wounds infected by penicillin-sensitive organisms were treated by suture, after providing for introduction of a solution of the drug through tubing. Results here were excellent also. By this time there was no doubt that the Australian-produced penicillin was yielding successes as dramatic as those on other fronts. Control of infections by organisms sensitive to penicillin was now assured. Acute staphylococcal osteomyelitis resolved without resort to surgery, and rapid recovery took place of acute pneumonia, meningitis, and certain urinary tract infections. Infected wounds of soft tissues were rapidly controlled, and granulating surfaces of burns and other wounds infected with staphylococci and streptococci usually were freed of bacteria in a few days. One significant finding was the return of staphylococci and streptococci after the treatment was suspended, and the common appearance of Gram-negative organisms. It is thus seen that further critical study of antiseptics in wounds was by no means discouraged by the introduction of penicillin.

It soon became evident, too, that penicillin could be used to make operative procedures safe, or indeed possible. The mechanical fixation of fractures was made virtually safe, and possible even in war wounds. Further, the application of plastic procedures was speeded and given much greater prospect of complete success by the intelligent use of antibiotics and antiseptics.

These advances will be detailed in the sections dealing with specialised surgery.

One other interesting advance may be mentioned here. An organised air evacuation service made it safe to send back to base areas men who were still having active treatment with penicillin. Three-hourly injections could easily be maintained by the nurse in the plane, beds in a forward area thereby being set free and the patient being moved to base without risk.

In the forward areas in the South-West Pacific Area trials proved very satisfactory as soon as supplies were adequate for wider distribution. Deep wounds of soft tissues inflicted by missiles of various kinds afforded good opportunity for such trials, as they varied from shallow tangential to deep penetrating or perforating injuries. The involvement of muscle and fascia in most of these was extensive, and a characteristic of wounds received in this tropical zone was their contamination with foreign matter such as mud and vegetable fragments, as well as clothing. The nature of the terrain also caused delays in the transporting of wounded to forward surgical units. Majors T. F. Rose and A. L. Newson collected the results of 108 deep soft tissue wounds treated by suture and penicillin. All these wounds were treated according to the surgical condition present, without regard to the time elapsing since injury.

Under a general anaesthetic, "Pentothal" for choice, the usual ritual of wound cleansing and excision was observed: deep fascia was incised to

obviate tension and to permit drainage from those recesses of the wound where infection was probably already present. All bleeding was stopped, and the raw surfaces were covered by a fine frosting of sulphanilamide powder containing 5,000 units of penicillin per gramme. If the wound appeared clean it was closed by deep interrupted non-absorbable sutures. If closure involved undue tension partial suturing only was practised. Wide destruction of tissue, swelling or evidence of overt infection were contra-indications for suture. Conditions of evacuation were also considered, as adequate supervision and continuation of administration of penicillin were not always possible. If suture could not safely be done the wound was lightly covered with "Vaseline" gauze. After this penicillin, 15,000 units, was given every three hours till infection by penicillin-sensitive organisms had disappeared. Radiological examination was carried out before operation if possible. Unsutured wounds were re-examined on the fourth or fifth day and any further necessary procedures carried out. If the wounds appeared healthy and not oedematous, suture was carried out and continued injections of penicillin given. Delayed primary suture was practised up to the tenth day after wounding, the procedure being "covered" by penicillin both before and after operation.

Bacteriological examination was carried out on infected wounds—usually mixed infections were found with penicillin-sensitive staphylococci and streptococci and Gram-negative insensitive bacilli. The latter organisms were effectively disposed of by the local application of "Monacrin" 1 in 1,000 on gauze or by its use as a drip through tubes, which were re-inserted every two days. Only *Ps. pyocyanea* resisted this treatment, but the addition of 2 per cent of acetic acid to the antiseptic solution gave good results.

Air force practice showed that certain wounds were not suitable for local application of penicillin, namely those sprinkled with particles of aluminium from bomb casings. These particles were harmless.

With combined parenteral and local treatment the infected wounds were usually suitable for suture, but not till well after the tenth day. By this time some trimming of the skin edges was necessary, and even under-cutting to avoid tension: if the lapse of time had brought with it much granulation tissue or scarring, a complete re-excision was necessary. One caution was found advisable. Tubes were not used for the application of penicillin in cases of delayed suture owing to the risk of infection or re-infection by Gram-negative bacteria. Due care was taken to keep the patient well nourished, with high-protein and vitamin food, and blood transfusion for anaemia, and any infective diseases such as malaria or hookworm were treated.

The results were very satisfactory, 91 out of 108 suture operations were successful, no further surgical procedures being necessary. Thirty-seven out of 47 primary sutures were successful, 30 out of 35 delayed primary and 24 out of 26 secondary sutures. Detailed survey of the results showed clearly the advantages of early closure of war wounds, both in the functional result and the saving of time and suffering.

Infection was of course the chief cause of delay in suturing, and it in turn was related to the period elapsing between wounding and the first surgical operation treatment. The time of healing for primary suture averaged 13 days, for delayed primary suture 17½ days and for secondary suture 27 days. The malign effect of infection is seen in the latter figures. Penicillin proved itself most effective in preventing clinical infection; penicillin-sensitive organisms seldom gained a hold in wounds excised within twelve hours of reception, general spreading infections did not occur, and no gas gangrene was seen.

Similar experiences in other areas proved that the ideal of early suture of deep tissue wounds could be more nearly obtained by the use of penicillin in conjunction with other correct surgical procedures. Good results were obtained with wounds of the buttock, by the daily introduction of 750 units of penicillin through a tube which proved effective and economical. Specialised experience was equally favourable with reparative surgery and with regional wounds involving the limbs and long bones, the thorax and the head, and to a less extent the abdomen. In short, penicillin allowed careful and thoughtful surgery to lessen the ever-present hazard of infection, and in some instances to reduce it to a very low point indeed. The necessary technical information was broadcast by a series of instructions to all medical units handling sick and wounded. One of these laid down a classification of the sensitive and insensitive bacteria, and those with great strain variability. Approximate dosages recommended in Technical Instruction No. 92 were as follows: non-resistant streptococci 100,000 to 200,000 units daily, staphylococci 240,000 units or more, daily and clostridia at least 200,000 units daily. Recrudescence of infection was countered by continuing maintenance dosage for some days after subsidence of temperature and other signs. A total of one half to one million units for parenteral treatment was advised. It may be remarked here that some confusion of thought arose about this time concerning "courses" of treatment. This was due to the custom of prescribing definite courses of sulphonamides so as to avoid the toxic effects of cumulative doses. With penicillin of course the position was entirely different, as toxic effects were due largely, if not wholly, to impurities and in any case were of such nature as could not be cumulative. The importance of rejection of this implied concept was emphasised by Florey in his personal teaching during his Australian tour and elsewhere. It was necessary to realise that the patient still had to build up his own immunity, and that penicillin should be continued until the risk of recrudescence seemed over.

Just as certain strains of bacteria became sulphonamide-fast, so also some became penicillin-fast, a biological survival phenomenon that was and still is a drawback, but really brings no serious criticism against the value of the drug.

Directions were also given for intrathecal injection in which only the sodium salt was used in isotonic saline or in distilled water. Either 10,000 units in 2½ to 4 c.cm. saline or 5,000 units in 20 c.cm. of water were advised. The value of *in vitro* tests of sensitivity of bacteria was stressed,

and also the occasional important divergence of *in vitro* and *in vivo* behaviour of penicillin.

A little later, notes extracted from the Medical Research Council War Memorandum were embodied in another Technical Instruction. This traversed the important features of penicillin and described the usual methods of dispensing and application. Once again the need for adequate surgical treatment was emphasised, and in infections by clostridia, the necessity for the use of all existing methods as well as penicillin. The importance of individual supervision and judgment was also stressed, not only in the treatment of deep flesh wounds, but especially in infected compound fractures. The advice of Florey and Cairns, that infected wounds involving bones should if possible be closed, was tempered by caution. Brigadier Hailes commented in his instruction:

"It is evident that in such cases discretion must be used, and each fracture considered on its merits. It would be most unwise to close a heavily infected fracture, penicillin or no penicillin, and most of us would be content to administer the drug parenterally and locally for a few days before reaching for the needle holder."

In infected thoracic wounds, on the analogy of successfully treated empyema, the advice was given to inject 15,000 to 30,000 units after aspirating the contents of a haemothorax, and to repeat the penicillin if subsequent aspirations were necessary.

In wounds of the eye a drop of a solution of 500 units to a mil of saline was prescribed every half hour or hour for the first twenty-four hours, thereafter increasing the interval. Later experience showed that even more frequent administration might be used for acute infections. The danger of contamination of penicillin eye drops was found by no means illusory.

Failures were dealt with also in this instruction; they were usually set down to lack of care in ensuring free access to all parts of the wound, undue disturbance of wounds and wounded parts, to greater tension on sutures, and penicillin resistance of bacteria.

Further notes on parenteral and local administration of penicillin were promulgated later. Prophylactic dosage with sulphonamides was retained as an invariable routine, continuing from the time of wounding until the patient came into the hands of a surgeon who decided whether dosage was to be continued or not. The battle casualties submitted to operation were treated usually at a field ambulance with penicillin given parenterally and injections of 15,000 units were continued every three hours. The initial dose for severe injuries was 50,000 units; this dose was given also immediately before operation, and if the operation lasted an hour or more the dose was repeated. This ensured a high titre of penicillin in the exuded blood and serum, which was a valuable prophylactic against the spread of infection. Antibiotic treatment continued until on the average 500,000 units had been given, but this was doubled in compound fractures. Fortunately by this time the output of penicillin was sufficient to meet all demands of adequate continuation of treatment.

When patients not receiving penicillin were operated on they received standard treatment for a couple of days if possible and a large dose before operation.

The issue of Instruction No. 108 in 1944 gave sanction to early wound suture, concerning which penicillin had now closed the debate. However, emphasis was laid on the even more meticulous application of surgical principles and practice. Adaptors were supplied to fit the bottle and the top of the standard metal insufflators, and wounds after excision were lightly powdered with the standard powder, 5,000 units of penicillin to 1 gramme of sulphanilamide. Suture was sanctioned only if conditions were suitable. Suture associated with the insertion of tubes for the instillation of penicillin solution was not considered a suitable method for areas on the forward lines of communication, where scrupulous and continuous supervision was difficult to maintain. Therefore such treatment was permitted only in stationary units.

With compound fractures a decision concerning suture was reached only after the surgeon had duly considered the nature of the injury, the blood supply, the possibility of retaining the patient, and the length and nature of the evacuation route. The distance between staging posts in difficult country was measured not in miles but in time. The wise suggestion was made that surgeons should proceed cautiously and accumulate their experience step by step, till their technique could be safely applied to the deeper, more serious lesions.

It was hoped that even where the surgical and environmental conditions did not permit primary sutures of wounds with compound fractures, a secondary suture would be possible in three to seven days. Gas gangrene or gas infection also precluded primary suture.

The only directions given about abdominal wounds were that in addition to the parenteral use of penicillin, local application of powder should be made to wounds excised on the body wall, in order to lessen the risk of the spread of infection in and below the skin.

In thoracic wounds 60,000 to 100,000 units were now advised for instillation into the pleura after operation or aspiration.

Primary amputation stumps were treated like clean wounds, by insufflation and closures, unless it was thought wiser to defer suture for several days.

Injuries to joints were treated either in standard fashion with closure of the joint or by leaving a small tube through which penicillin solution 250 units to 1 c.cm. could be introduced. In the knee joint closure was recommended, penicillin being introduced for some days afterwards into the joint space, either by puncture and preliminary aspiration or by instillation through small tubes.

Use of the standard powder of sulphanilamide and penicillin fulfilled most of the needs for local application. Care was taken, even in large wounds, not to exceed a total of 10 grammes of the powder used in insufflation. Lanette wax cream was unobtainable in Australia at the time,

but substitutes were devised. One drawback to this vehicle was not only its inherent limitation, but the rapid deterioration of the penicillin.

Special directions for meningitis were given which are described in the section on that disease.

The wide application of these measures in the closing stages of the Pacific war produced excellent and far reaching results. More than ever it gave opportunity to the surgeon to practise his art as well as his science. Penicillin was a saver of life and of bodily structure and function in many instances. Its harmlessness and potency made it an adjunct to careful surgery, in spite of its limitations and bacterial selectivity. In special fields it had special victories, as in wounds involving long bones and large joints, in infected thoracic wounds, and where the meninges were involved in head wounds. In secondary haemorrhage it had a place also, lessening the risk of infection in weakening the walls of blood vessels. It can be said too that the caution impressed on young Australian surgeons, and the encouragement given them in following correct principles in circumstances where rougher methods might easily have been condoned by some, bore fruit when the partial conquest of wound infection became possible.

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CHAPTER 33

TRAUMATIC SHOCK

A FULL account of traumatic shock cannot be presented here. The experiences of a long war have given us better understanding of the physiological problems involved, but our knowledge is still not complete.

The true basis of humoral shock was recognised by W. B. O'Shaughnessy in 1831 in an enlightening communication on the treatment of cholera, but even in recent times peripheral circulatory failure has not always been understood, and has been confused with failure of the heart.

The histamine hypothesis of 1919 was no longer found adequate, and in 1940 was replaced by the views of Blalock and others who have shown that the symptoms and signs of shock may be explained by the loss of circulating fluid into the injured part. The curious special instance of the "crush syndrome" has, however, reminded us again of the possible importance of chemical and reflex phenomena, as well as of more purely physical mechanisms. The clinical features of traumatic shock appear to be well explained by an interplay of compensatory and decompensatory phenomena, as shown by the experience of Zweifach and others in 1945.

Fluid loss, especially blood loss, soon after injury inaugurates a compensatory mechanism which is characterised by arterial vasoconstriction, augmented response to adrenalin, capillary ischaemia, haemo-concentration and increased spontaneous arteriolar contractility. This increase in the normal periodic contraction and relaxation of arterioles affects the local circulation in the capillary bed, and the prolongation of their phase of contractility is protective in nature. It has been shown that the serum from animals in this phase of shock is vasoexcitor. If death occurs at this early stage the post-mortem findings may be predominantly compensatory, the most notable findings being those due to ischaemia. If the patient survives up to this point the phase of decompensation follows, and if loss of blood and that of plasma are combined and severe the stage of compensation may be very brief.

Decompensatory reactions last longer and cause progressive slowing and eventual suspension of the periodic contraction of arterioles and intense congestion of blood in venules and capillaries. Experiments have shown that the serum at this stage has a vasodepressor effect on control animals. The peripheral vascular tone may be relaxed while the arteries are still constricted, but later they too are affected by decompensation.

It will be seen from these considerations that a balance of the processes of compensation and decompensation, depending on a variety of causes, will determine the issue.

In the decompensatory phase, the capillary blood flow may become so slowed that the state becomes irreversible and a fatal result must supervene. It has been postulated that during prolonged hypotension changes may occur in the damaged tissues which may produce a chemical toxaemic

factor, and thus a vicious circle. Fluid replacement can be effective only before these tissue changes occur; after that it is valueless. Deprivation of oxygen and nutriment can be tolerated by the body cells for only a limited period. This is not accurately known: for nerve and muscle the period may be only a few hours.

Study of the "crush syndrome" and similar conditions has shown that profound oligaemia may produce serious and peculiar dysfunction of the kidney, due, it would appear, to a vascular spasm which shunts the renal circulation from the cortex. Delayed effects may appear during the first and second weeks after injuries causing ischaemic necrosis of tissue, chiefly hypertension and uraemia, and death may ensue from pulmonary oedema and uraemic cachexia. It is continued action of the causal factors of the oligaemia that is so dangerous, and therefore in states in which this may occur replacement of lost blood may not alone be effective. Such states are the crush syndrome, severe burns, intestinal obstruction, and special types of infection, such as gas gangrene or continued bone sepsis.

Some understanding of the dynamics of traumatic shock is of greater value than a mere listing of its possible causes. The causes are usually stated as being neurogenic, oligaemic, renal, mechanical, toxaemic and chemical. With the exception of such mechanical causes of circulatory collapse as embolism due to fat or clot, these "causes" are in part at least stages in a continuous, though often fluctuating, set of phenomena. To assess the exact physiological stage of the condition of patients suffering from shock is a problem of the first magnitude. "Resuscitation" has come more and more to mean timely and adequate replacement of body fluids. This knowledge was reinforced by the experience of the 1914-1918 war in which the now standard resuscitation methods were applied with great success by specially trained and skilful teams. A War Office brochure on resuscitation was issued in 1944, and this, with some local amendments, was adopted for the use of the Australian Military Forces.

Traumatic shock was dealt with in one of a series of special articles in *The Medical Journal of Australia* on war medicine and surgery compiled under the direction of the National Health and Medical Research Council of Australia.

In these publications the following important practical points were stressed: that replacement of the blood volume rather than of the red cells was the first essential, that haemo-dilution is a characteristic response to loss of blood, and that true traumatic shock may exist for some time before a fall of blood pressure is detected. The man who has lost blood obviously needs corpuscles as well as plasma, but they are not his prime need. Further, tests revealing haemo-concentration are not necessarily an accurate measure of the degree of shock from which he suffers, and in addition, compensatory vasoconstriction may maintain his blood pressure for some time, even in the presence of shock, and so prove deceptive.

The essential differences must be realised between traumatic shock due to a rapid and heavy loss of blood, and that due to an injury such as severe burns. A "resuscitation officer" in the field needs clinical acumen and

judgment of a high order to decide quickly what a wounded man needs most, whether it be quiet and rest only for the time being or immediate transfusion. *Triage* is an important duty in a forward surgical station.

A patient's initial condition is not always a sure guide: the nature and extent of his wounds must be ascertained if his true state is to be properly assessed. A systolic blood pressure of 70 to 75 millimetres of mercury is usually regarded as the critical level, but this may be a later sign of severe shock. Haemo-concentration, a valuable sign in some injuries like burns, may also be deceptive. The so-called "classical" picture is like all such type descriptions; it is not a phenomenon which can be relied upon to appear when danger threatens. However, the appearance is distinctive if a pallid patient is seen, cold on the surface of the body, especially on the extremities, with increased pulse rate and falling blood pressure, thirsty, often apathetic, and perhaps somewhat dulled of sensation. More ominous is the alert, garrulous man, perhaps euphoric, perhaps anxious; his falling blood pressure and peripheral cyanosis presage a state which is irreversible and ends in death. A dangerous transition stage is the so-called hyperkinetic phase seen late after massive bleeding. In this there is vasodilatation with warm limbs and a bounding rapid pulse, but the picture may soon change to coldness and pallor. In the former stage immediate transfusion may not be without risk of pulmonary oedema, a danger which may be overcome by a slow transfusion of packed red cells. Severe and untreated wounds sometimes call for caution also and a slow initial transfusion rate is occasionally desirable. Fat embolism, pulmonary embolism and pulmonary blast are conditions in which there is a risk of producing pulmonary oedema by the introduction of any considerable bulk of fluid into the circulation. Obviously the aim in treating traumatic shock is to diagnose accurately the pathological condition underlying the patient's condition and to anticipate any phase of deterioration so that the cycle may be broken before it becomes irreversible.

The accessory factors in treatment are also important. The value of warmth was overstressed in the 1914-1918 war because of climatic conditions, and it has been found since that the application of external warmth is not without risk. Following injury a significant difference has been found in the volume of limbs in cold and warm baths, and fluid loss from the circulation of a damaged limb may be reduced by cooling.

Conversely, caution should be observed in raising the temperature of the skin, lest the protective vasoconstriction give place to dilatation. R. D. Wright and John Devine point out that a drop in the internal temperature is not usual in shock, though the mouth temperature may be subnormal the rectal temperature is more reliable, and should be used as a guide to the external application of heat. Heat should not be applied unless facilities for the restoration of fluid volume are to hand. It is recognised now that the conservation of body warmth at its correct level usually requires enough insulating covering to prevent heat loss, and sometimes, under conditions of severe cold, as occurred in the Western Desert at night, additional external heat. Like many other practical applications of physiology, the

application tends to last as a ritual after the physiology has been forgotten and neglected. It should be remembered at least that "shock cages" are usually dangerous, and that severely damaged limbs should never be warmed.

Pain must be relieved if present. Sometimes the clouding of consciousness due to shock mercifully extends to the diencephalon and morphine is not needed. When it is needed it may not be easy to get it into circulation owing to the sluggish capillary flow. Cumulative action of several doses has occasionally caused dangerous degrees of morphinism. Intravenously administered morphine was often found valuable by medical officers. Anxiety of mind may be as bad as pain; rest and quiet if obtainable, together with reassurance and provision of some bodily comfort will alone improve the condition of many patients. Many forward surgical units noted how the condition of ill or wounded men, fatigued by an uncomfortable journey, improved noticeably after they had been shaved and fed.

Fluids by mouth are almost always an essential. All men who are conscious, except those who have abdominal wounds, should be freely given fluids to drink. Hot sweet tea was usually popular, and in providing an ample supply of this social and medical necessity chaplains and members of auxiliary services often did invaluable work. Yet the practical aspects of the oral route for administration of fluids were sometimes overlooked. The value of this anti-shock measure was clearly stated in 1917 in a report by the Medical Research Council, but in 1940 in the first Western Desert campaign it was sometimes shown that memory is short. Other methods of fluid replacement are considered in full in the following section on blood transfusion. The threat or actual occurrence of ileus in abdominal injuries led to the logical development of fluid replacement by the special measure of continuous gastric or duodenal suction, combined with parenteral infusion of fluids. This is mentioned here to draw attention to the need for maintaining a due balance of water and electrolytes in the body fluids in those forms of abdominal trauma which may cause further dehydration.

The signs of dehydration may not be easy to recognise if attention is diverted by the state of severe wounds. The War Office handbook on resuscitation aptly remarks: "If the medical officer will always consider the possibility of dehydration he will have gone far towards prescribing the best treatment".

Oxygen administration is not necessary as a routine measure. Indeed the anoxia of the wounded is not usually anoxic in origin, but when the mechanical factors of a chest injury are present, or when capillary stagnation is in evidence oxygen is indicated. A practical difficulty in a field unit is that attention is necessary by some adequately trained person for its administration.

The decision as to the form of treatment indicated for any given patient in need of resuscitation rested in the field on clinical considerations. Certain precise measurements were of assistance: estimations of pulse rate and blood pressure are of course necessary parts of a clinical examination. If

local facilities permit, haemoglobin estimations are in this category also, and in the later years of the war a simple method of determining the specific gravity of blood and serum was generally available. Where wounded men could quickly reach a relatively stable forward base these tests could readily be applied, with perhaps in addition the haematocrit reading. The copper sulphate method of the falling drop was adopted as standard. Readings of the specific gravity are easily made by this test, as each drop of the standard solution is coated with copper proteinate and remains discrete for as long as 20 seconds. Neither the size of the drop nor temperature impaired the remarkable accuracy of this test, but like many another precise measurement its interpretation was more difficult. In burns, and in crush and blast injuries the specific gravity of the blood was a reliable index of the degree of shock and of the amount of extra fluid needed in the circulation. But in injuries complicated by continued bleeding and in extensive haemorrhage it was easy to be misled if the haemo-concentration index alone was taken as a guide. If no dilution of blood had taken place, this index was most easily determined in any case by a simple estimation of haemoglobin. These observations in no way invalidated the specific gravity test in other conditions, such as continued sepsis or prolonged fevers. Control of intravenous infusions is important, so as to avoid the risks of unrelieved dehydration and overloading of the circulation, with consequent oedema of the lungs and other tissues.

Biochemical methods, such as described above, have been found of value, provided the fallacies are realised, and corrected by close clinical study of individual patients. Majors A. E. F. Shaw and A. Daly Smith published the results of the study of fifty cases, in which they used estimations of haemoglobin, haematocrit readings, the plasma protein level of the plasma, and plasma chloride content. They concluded that the haematocrit and plasma protein findings were of value in indicating the need of intravenous therapy and the type to be used. They found these methods most useful in the less acute varieties of shock, and realised that without other data such as blood volume and the amount of the electrolyte and fluid reserves caution is required, especially in acute states. H. H. Kretchmar has also constructed a useful nomogram which indicates the degree and type of fluid loss and its compensation.

Experience in resuscitation under varied conditions has shown that while standard routines could be adopted with advantage, judgment based on many factors and often on serial observations was most valuable. The choice of fluid was sometimes dependent on opportunity: blood was nearly always available from donors, whereas serum or plasma was not always at hand. Reconstituted plasma was not as valuable as at first it appeared. These matters are dealt with in the next section. Mention may be made also of two subtle and dangerous sequels of injuries treated by fluid replacement. These are anaemia, appearing some days after stabilisation of the circulation has been obtained, and hypoproteinaemia, occurring at a later date. Both of these were often concomitants of infection, and

could seriously retard healing and recovery. Transfusion of whole blood is obviously indicated.

The accepted practice for resuscitation during the war was well stabilised by 1942 and may be given as follows: (1) arrest of bleeding, (2) tilting the patient's head downwards, (3) assuring that he is warm, but avoiding overheating and sweating, (4) relief of pain, (5) administration of fluids by mouth unless specifically contraindicated, (6) early intravenous use of fluids, and (7) use of oxygen if necessary. It will of course be recognised that the distribution of oxygen by the blood must be adequate for the last measure to be effective.

Little mention has been made here of the effects of toxaemia as a cause of continued shock. The importance of this was well understood in the medical services, where bacterial toxins were a causal agent. The special instance of the crush syndrome was not met with, except rarely, in the Australian forces: it is briefly dealt with elsewhere. The action of bacteria in sustaining shock was dealt with on the prophylactic lines which form one of the chief ends of war surgery.

No special clinical research on shock was carried out in the Australian forces, but close touch was maintained with the work done in England and America. In particular the work by Green and others on the depressor substances such as adenosine triphosphate liberated from damaged tissue, such as muscle, was of interest since research on this and similar subjects had proceeded for some years at the Walter and Eliza Hall Institute of Medical Research. References to literature by Kellaway and others may be found in the reports of that Institute. Further information on field researches will be found in the clinical section of the British Medical War History.

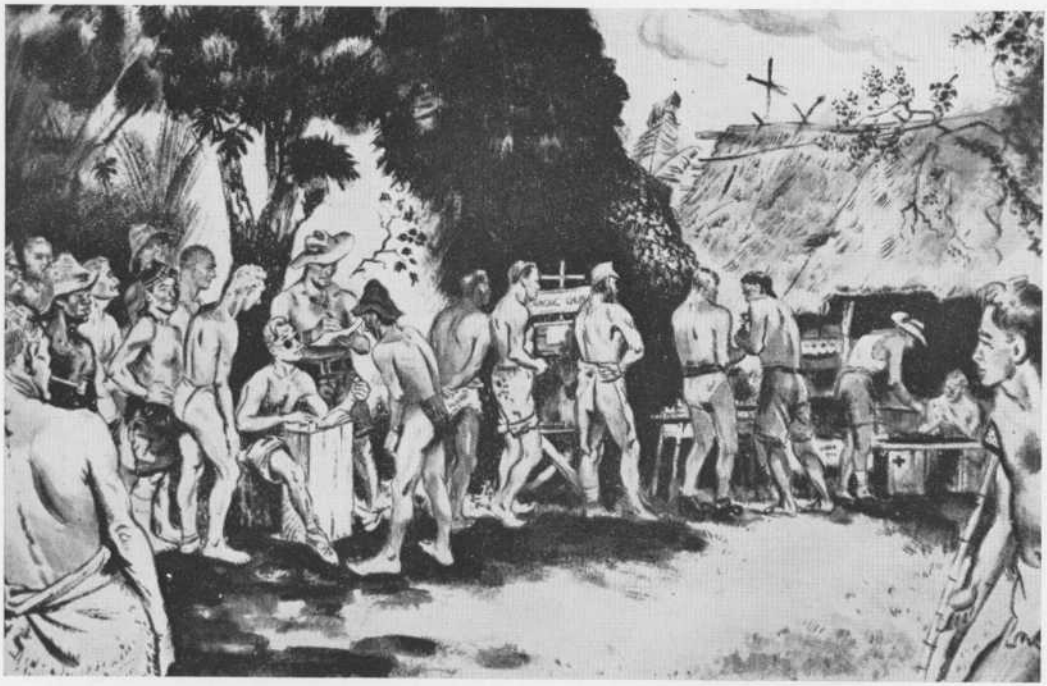
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(Australian War Memorial)

Direct blood transfusion method.



(Drawn by A. G. Old)

Routine blood typing at Chungkai.



(Australian War Memorial)

Grouping blood specimens "tile method".

CHAPTER 34

BLOOD TRANSFUSION[1]

IN the years preceding the 1914-1918 war blood transfusion was seldom practised owing to the technical difficulties produced by the clotting of the blood. The first successful device used to delay clotting was the method of coating of the inner walls of the apparatus with a thin layer of paraffin. Kimpton's tube was found the most satisfactory, and special teams were trained in the technique. Blood transfusion was thus employed in the forward areas by surgical teams. Later the citrating of blood was introduced, the difficulty of coagulation being thus overcome and storage being made possible. It should be recognised that resuscitation, in which blood transfusion was used as the chief therapeutic measure, was highly advanced in the later stages of the 1914-1918 war, as described in the medical history which sets out the organisation and work of special resuscitation teams.

Infusion of other fluids like saline solution was widely used also, but the rapid diffusion of these fluids through the capillaries into the tissues gave them only a temporary value. To overcome this gum acacia was introduced to provide a colloid solution which would remain in the circulation long enough for equilibrium to be established.

It was used extensively for a time and appeared to give moderately good results, but later work showed that although the blood volume was increased, certain detrimental effects ensued. Animal experiments provided evidence that the acacia produced a toxic change in the liver. Moreover, the acacia coated the red corpuscles and lowered their oxygen-carrying capacity. With the passing of years gum acacia fell into disrepute and was not used in the present war except by a few misguided enthusiasts. Its use in the Australian Army was very limited.

All these experiences in blood transfusion and infusion of physiological fluids were collected together in an excellent publication by the Medical Research Council of Great Britain. Despite the high standard of this work, many of its lessons were forgotten and had to be learnt afresh in 1939.

During the twenty-one years which elapsed between the two world wars, much progress was made in the science of blood transfusion. Two major advances were, firstly, the massive blood transfusion as first described by Marriott and Kekwick, and secondly, the storage of blood in blood banks which was first practised on a large scale in the Cook County Hospital, U.S.A.

In Australia, the greatest advance in this period was the establishment of blood transfusion services throughout the country, particularly by the Australian Red Cross Society. These services enlisted the help of civilians

[1] This article is based on a special contribution made by Colonel I. J. Wood: The section on Preparation, Preservation and Use of Wet Serum is by Major R. J. Walsh.

who volunteered to give a pint of blood to any persons requiring urgent transfusion. Medical officers tested prospective donors for their blood grouping, and excluded syphilis and any other ailment which would make their blood unsuitable. Transfusion services were later established in the larger country districts, the work being carried out either by the local Red Cross Society or by other philanthropic bodies.

In Australia, the pioneer work on blood storage began in the Royal Prince Alfred Hospital, Sydney, where blood was collected under conditions of strict asepsis and stored in an ice chest for periods up to a week and then given to patients requiring urgent blood transfusion. Later, improved methods of blood storage were investigated at the Walter and Eliza Hall Institute of Medical Research in Melbourne and the first blood bank for general use in Australia was established at the Royal Melbourne Hospital. The two main problems which were studied were the determination of the best preserving anti-coagulating fluid for prolonging the life of the blood corpuscles and the most suitable maintenance temperature. The lower the temperature the longer the life of the individual corpuscles, at least down to about 8°C., and the greater the inhibition of growth of any bacteria which may have gained access during the collection. However, if the temperature fell below 5°C. the blood was difficult to administer, and freezing of the blood caused haemolysis, and was therefore unsafe.

This experience enabled a joint service to be established in Victoria by which blood obtained through the Red Cross Society from suitable donors was stored up to a period of fourteen days in the Hall Institute. Valuable information was thus gained concerning the ever present danger of bacterial contamination. Haemolysis in stored blood, though not necessarily due to infection, could be caused even by non-pathogenic organisms, setting free haemoglobin which could cause serious and even fatal results through renal block and other embolic phenomena. Similar organisations were set up in most of the States, sufficient to cater for present civilian needs but capable of expansion to meet greater requirements.

At the outbreak of war the need for an organisation to provide for blood transfusion in the Australian Army was apparent. Major-General Downes, D.G.M.S., who had just returned from a world tour, and was much impressed by the work carried out for the War Office, took steps to form a blood transfusion section. Suitable equipment had already been designed by Australian Army officers, Captain C. W. Ross and Captain I. J. Wood, combining the results of work carried out overseas and at the Hall Institute. Despite great difficulties in obtaining raw materials and skilled labour, the apparatus adopted as standard for the Australian Army was produced in time for blood transfusion panniers to form part of the equipment of the 16th Brigade A.I.F. which left for the Middle East on 10th January 1940. Only minor modifications were made in the apparatus, whose general principles were retained throughout the war. Criticism was levelled at this piece of equipment, as was inevitable, and preference was expressed by some for the British type.

As will be shown later, in spite of some advantages in other apparatus the Australian equipment fulfilled all the purposes for which it was designed. These were as follows:

1. To provide a means for collection and immediate transfusion of a liberal volume of citrated blood.
2. To enable blood collected under ideal conditions of asepsis to be stored at a suitable temperature for ten days or more with a minimum danger from infection and haemolysis.
3. To provide storage of physiological solutions, particularly glucose-saline, which could be produced in bulk by commercial firms, or in case of need under service conditions, and which could be relied upon to withstand the test of time, rough handling and tropical conditions.
4. To permit storage of serum collected aseptically under ideal laboratory conditions.
5. To furnish means of giving intravenous infusions of special drugs, such as antibiotics, analeptics, anti-infective agents or anaesthetics.
6. To provide simple and effective equipment for special surgical techniques of suction or irrigation, as applied to the thorax, the alimentary tract or the bladder.

The Australian set incorporated a mass-produced infusion set, the "Soluvac", made by Elliotts and Australian Drug Proprietary Limited of Sydney. This apparatus was a modification of the original sealed gravity feed infusion sets first designed in America and widely used through the English speaking world. One of the valuable features of this set was its large capacity, one litre. Early in the war this feature was disparaged by advocates of the British set which used a container holding one pint of blood. Brigadier Hailes, Director of Surgery in the Australian Army, and Air Vice-Marshal Hurley, Director-General of the R.A.A.F. Medical Services, vigorously countered such criticism, maintaining that the drawbacks of greater size and storage space in transport were more than offset by the advantage of encouraging the transfusion of liberal quantities of blood.

Each blood transfusion pannier contained 10 litres of a selection of saline, and glucose-saline or serum according to needs, 5 giving sets, 5 blood filters (chiefly for use with stored blood), 2 collecting sets, 2 sets of instruments and accessories, including 2 grouping sets, 20 ampoules of 100 c.cm. citrate-glucose solution and spare parts. Experiments showed that ice was the best refrigerant for blood storage under adverse conditions, as it produced an even temperature of 6°C.; electric refrigeration was subject to the risk of freezing through trouble with thermostatic control, and fuel refrigerators were not immune from similar troubles. The Red Cross Society arranged for the production of a coloured cinema film designed for use in the training of medical officers and nurses in the use of the standard blood transfusion apparatus. This was found of great value.

MOBILE BLOOD BANK

A special mobile unit was constructed to designs of Captain Ross, and its construction called for a great deal of hard work and ingenuity. It was completed by December 1939, and comprised three vehicles. A truck was fitted to transport standard well-insulated ice chests, and had an attached trailer carrying an ice-making unit. A van carried steriliser, still and washing plant, and provided room for collecting blood from a donor. This unit was tested satisfactorily on a journey from Melbourne to Sydney and was shipped to the Middle East. Unfortunately the Norwegian ship *Tirranna* carrying the equipment was captured by an enemy raider and later, while under German control, was sunk by a British ship off the French coast. One other mobile unit was built in Australia, but too late to be of use in the Middle East; it could not be used in New Guinea owing to the difficult terrain, quite unsuitable for such vehicles.

British mobile storage vans were used with success in the Western Desert; they were light, equipped with balloon tyres and electric refrigeration.

BLOOD GROUPING

Australian experts strongly advocated the mass grouping of the blood types of all troops in the A.I.F., and this routine was approved by the Military Board on the recommendation of General Downes. It is curious now to recall that some hesitation was felt officially in making this compulsory, on the grounds that many soldiers might resent having their blood taken. The lack of psychological insight in this view was shown by the universal ready acceptance of blood typing by servicemen and women. The actual work of grouping in the early days was done with commendable efficiency by civilian pathologists under stress of time, but even the first units of the Second A.I.F. had this important test completed before embarkation by a team organised by Major E. F. Thomson. The 16th Brigade's groupings were completed in less than three weeks. Each soldier's blood grouping was recorded in his pay book (later "record of service" book) and stamped on his identity disc. The accuracy of the grouping was of a very high order. Checks made in the Middle East and Australia showed a negligible proportion of errors, and although cross checking for compatibility was advised and was carried out whenever practicable, no accidents due to incompatibility occurred, even when the recorded grouping was taken at face value.

In Greece at the 2/5th Australian General Hospital after capture by German forces, Major Brooke Moore gave about 100 transfusions using Australian convalescents as donors, and always found their grouping accurate. In 1943 a rapid cross-matching method was described by Flight Lieutenant C. B. Hudson, in which blood haemolysed by freezing was used instead of serum or plasma. The notation adopted was a combination of the Moss and International, that is, AB1, A2, B3, O4.

A standard tile method devised by Wood and Ross was adopted in the army for ascertaining blood groups. Rectangular tiles were used of

moulded glazed porcelain, 11.8 x 17.5 centimetres. These were mounted in wooden frames to facilitate handling and shaking, and were divided on their upper sides by ridges into 24 equal squares each with a cylindrical depression in the centre. For each test 0.1 c.mm. of 1 per cent suspension of red cells was added to 0.1 c.mm. of A, B, and O serum in each of 3 cells, leaving the fourth for any needed repetition. Mixing was done by a horizontal rotatory movement, and the results were read for all six tests on each tile immediately, again after 15 minutes and again before the result was recorded at the end of 30 minutes. Agglutination occurs more slowly in the depressions than on flat glass slides. Macroscopic readings were confirmed with a hand lens if necessary, and finally passed to an independent observer, though there was seldom any difficulty in deciding the end result.

At the Walter and Eliza Hall Institute in Melbourne, the percentages were worked out for the blood groupings of the first 176,943 members of the defence forces tested there. They were as follows:

Group AB (1)	2.9 per cent
Group A (2)	39.88 per cent
Group B (3)	9.73 per cent
Group O (4)	47.49 per cent

These figures agreed very closely with those found for blood donors in the Red Cross services, which are checked very carefully, and therefore are an indication of the accuracy attained by the standard method adopted. This accuracy is due not only to the care taken in all centres where the work was done, but also to the use of high titre agglutinating serum, and the use of group O serum in the tests as well as A and B, as the anti-A agglutinins of group O are often more potent and read more rapidly with cells of sub-group A (2) than those of group B (3) serum. A long interval, half an hour, was also insisted upon before final readings were taken.

The preparation of serum, both "dry" and "wet", was undertaken by the various transfusion services. The work done by these and in particular the reasons for selecting pooled serum as the mainstay for infusion fluids to replace blood will be described later. Mention must be made here, however, of the early use of serum prepared in Australia. Fresh ground was really broken when liquid serum was taken overseas by Captain S. W. Williams in 1940 as personal baggage in order to test its capacity to withstand keeping at ordinary temperatures. Doctors E. V. Keogh and S. W. Williams during a visit to America in 1939 studied work being done on dried serum, and Keogh suggested that if liquid serum could be kept successfully at ordinary temperatures, much trouble would be saved. With the cooperation of Dr F. G. Morgan, of the Commonwealth Serum Laboratories, quantities of serum were obtained for experimental trial in Australia and overseas. Serum taken to Palestine by Williams was successfully used one year later on a patient in the 2/1st Australian General Hospital at Gaza. Meanwhile large quantities of serum were being pre-

pared in Australia, and from Melbourne, Sydney and Adelaide supplies of both liquid and dry serum were sent overseas. Human liquid serum had been stored for considerable periods before 1939 in England and America and elsewhere, chiefly for its antibody content, but such storage was under standard conditions at low temperatures. Though desirable, this was found not to be necessary. Processes for drying serum were then well advanced also, but the idea of keeping liquid serum at atmospheric temperature, for long periods if necessary, does not seem to have been entertained before.

It is now best to follow the application of blood transfusion in the field, and to see how these experiences added to knowledge or modified policy. In the earlier campaigns in the Middle East surgeons in the field agreed with expert opinion at home in preferring "wet" to "dry" serum, quite apart from the lessened labour in producing the former, for reconstitution with distilled water was less simple than the direct use of a ready container.

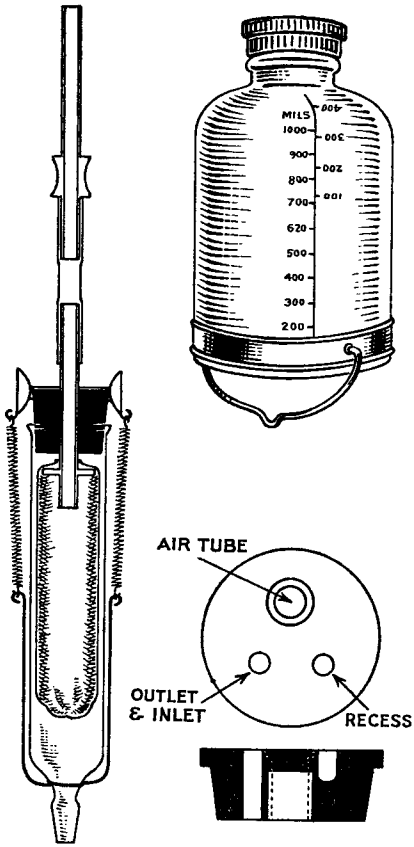
Huge quantites of glucose-saline were also prepared throughout the war, in fact, the demand for glucose-saline was double that for blood and serum together. The wisdom of using standard commercial apparatus for the storage, distribution and administration of physiological solutions was soon apparent. Most medical officers were familiar with the use of the "Soluvac" flasks, or were readily trained in the technique. Though a wide choice of fluids was at first available, time proved that 5 per cent glucose in normal saline was more generally useful than any other. Intravenous fluids of various kinds were at times used as convenient vehicles of drugs, such as analeptics or anaesthetics, which could be introduced at a desired concentration and rate by adding them to the bulk fluid or injecting them through a rubber connection.

Trouble was experienced in the Middle East with mould infections in glucose solutions, especially towards the end of the summer of 1941. This was thought to be in part due to the fact that the glucose-saline from Australia was arriving in flasks suitable for storing blood, and errors in their more complicated sealing assemblies were not infrequent. Many flasks showed caramelisation and fine flocculent precipitation, but these were found later to be free of pyrogenetic substances. The most serious problem was contamination with moulds which grew down from the stopper into the fluid. It appeared that the size of the bung assembly tended to facilitate the entry of moulds or their spores. Technical Instruction No. 22 was issued on the subject in which all the abnormalities of appearance in these fluids were described. Solutions, quite clear, though slightly yellow, due to caramel formation from glucose, could be used safely. Those with a suspension so fine as to be difficult to see were also passed for use, as the appearance was only due to a silicate compound from the glass. Moulds caused a dark deposit, a coarse flocculation, a white or yellow deposit of mushroom or weed-like type, or a stringy turbidity. It was imperative to discard these flasks. Any flasks with cracks, or evidence of faulty

assembly, in particular lack of vacuum when the rubber diaphragm was removed, were also discarded.

The number of contaminated flasks was still considerable in 1942, when the island campaigns began, and a high proportion of the flasks arriving in New Guinea showed gross mould infections. Accordingly, Professor H. K. Ward was asked by the D.G.M.S. to investigate the cause of the mould formation. On his recommendation the original capping of the bottles as used in the commercial product was resumed, with great improvement.

Refilling of bottles was undertaken on a moderate scale in the Middle East. Later the resources of the British Transfusion Service were used for this work. It was found possible to carry out some preparation of physiological fluids in the pathological departments of general hospitals, with the help of additional equipment, such as special stills, though the inroads on time and resources caused by such work were considerable when a hospital was already busy. It must be remembered too that the necessary routines of cleaning apparatus and containers after blood transfusions require time, experience and training. The establishment of a blood bank even on a small scale illustrates the great care demanded.



Details of transfusion flask and filter.

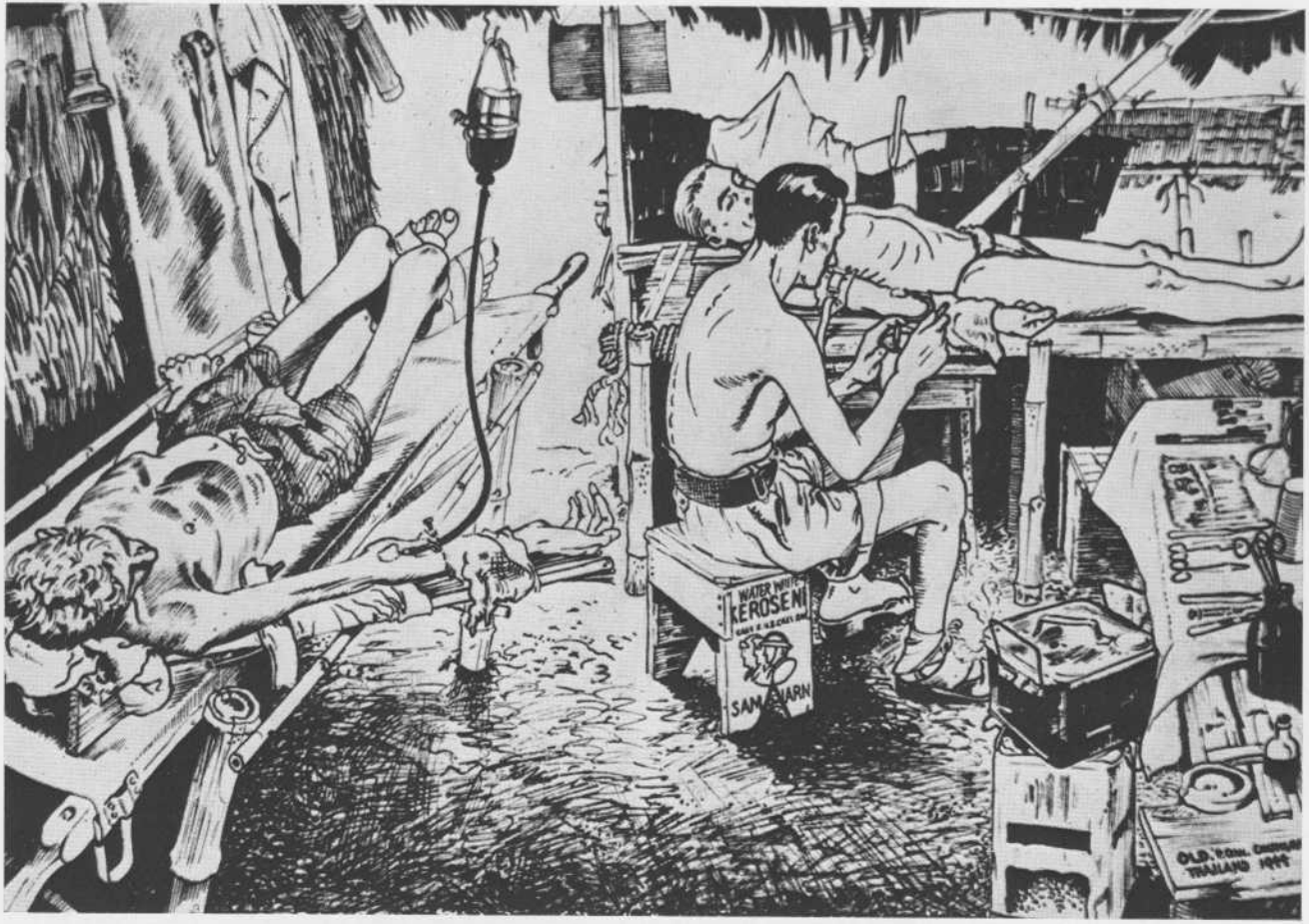
Without further discussion of administrative questions references may be made to the principles adopted by the A.I.F. in the Middle East with regard to blood banks. Early in 1941 a conference was held between British and Australian experts at the 15th British General Hospital. At this the different methods were made clear. The British blood bank had a mobile section which worked well as a unit, centralising the work but dependent on transport. The smaller Australian force relied on a decentralised method, carried out by ensuring a high standard of efficiency in all field medical units, including field ambulances. Small blood stores were used, but blood was also obtained from walking wounded. This decentralisation served a useful purpose then and later, by diffusing knowledge of techniques among the members of the medical services. It also lessened risk of infection, and offset some of the difficulties of transport.

Training in the use of a standard equipment began as soon as possible. In Australia medical officers gained experience in civil hospitals using army equipment, and in Middle East training was further pursued. A 16 millimetre film produced by the Australian Red Cross Society, and shown with a projector bought in Jerusalem by the Red Cross, was found very useful. So too was training on "patients", fine rubber tubing strapped on their limbs being used to represent veins. Australian medical officers also visited the British transfusion units and received great help from Colonel J. S. K. Boyd, Director of Pathology, and Major G. A. H. Buttle, who had formed a large transfusion centre in Cairo. In November 1940 Major I. J. Wood, A.A.M.C., was given facilities for working in transfusion with a British casualty clearing station at Buq Buq in the Western Desert, and also with other forward units. This close liaison at this stage in the desert campaign was most helpful then and later.

Blood banks were begun at Australian general hospitals also, the pioneer work being done in army huts at the 2/2nd Australian General Hospital under Major E. V. Keogh. Donor troops and convalescents supplied the blood, which was stored up to fourteen days in ice chests originally made for the mobile blood bank. This centre was controlled by a medical officer and also employed permanently a member of the nursing staff, Sister E. B. Roberts, who continued doing transfusion work till the end of the war. The value of specially trained nurses in transfusion work became obvious; they became skilled in typing, haemoglobin estimations and all routines, and played an important part in training other transfusion workers. This centre also turned out 800 litres of glucose-saline, and 500 litres of this were administered at the hospital without any reactions. Physiological fluids were also produced by the Pathology Department at the 2/1st Australian General Hospital. Some of the apparatus used in this work was made in the Hebrew University Laboratories. About this time also help and advice were given by A.I.F. medical officers to Jewish civilian transfusion-centres then being organised in case of air attack or invasion by enemy forces.

TRANSFUSION IN THE WESTERN DESERT

The first serious call for blood transfusions by Australian forces was during the battle of Bardia in January 1941. Resuscitation was carried out at the combined field ambulance main dressing station. Some trouble was experienced with the use of the apparatus, but this was due to the impracticability of surgical treatment and resuscitation being carried out by the same medical officers. A special transfusion team was sent to the desert in time for the first battle of Tobruk. In a special resuscitation tented ward connecting with the theatre of the main dressing station the team of one medical officer and two specially trained orderlies worked with five other ambulance orderlies. Patients needing resuscitation were examined by this medical officer and a member of the surgical team. Seven per cent of the casualties needed transfusion, and there was no difficulty



The taking and transfusion of blood, Chungkai. *(Drawn by A. G. Old)*



Blood serum being given to wounded at R.A.P. in Cape Karawop area.

(Australian War Memorial)

in collecting 46 pints of blood from 51 donors, chosen from walking wounded and members of the ambulance staffs, at their own request. Groupings taken from pay books or identity discs were accepted without cross typing. The only reactions were due to pyrogens from water used in cleaning the apparatus, and they were only of minor nature. Italian prisoners were given blood collected from their own walking wounded after typing had been carried out, and untyped British wounded were given group 04 blood. One Italian prisoner was successfully transfused after being wounded while carrying a wounded Australian to cover. Most of the vene-punctures were done without anaesthesia except where a cannula was used, and each bottle was filled with blood from two donors of the same group: these procedures saved considerable time. Fifty cubic centimetres of 4 per cent sodium citrate solution with 1 per cent glucose were used as an anti-coagulant and no clotting was encountered. A pint of blood added to half the contents of a flask of 5 per cent glucose in normal saline was also used with success. Ice was brought in the ice chests on a truck and enough remained after eight days to enable blood to be stored in Tobruk after its capture. In all, this stock of ice lasted eleven days, and 50 pints of blood was stored for one to five days. Ice was obtained later from ships in Tobruk harbour and other seaports. Blood was used within one or two days whenever possible. The rate of administration was usually one pint in half to one hour, increased to a pint in fifteen minutes to exsanguined patients. Haemoglobin estimations were only of limited value as a guide to the volume given which was based rather on the general state of the patient and his circulation. Even at this stage of the desert campaign the value of glucose-saline solution was evident in forward areas when paralytic ileus ensued after abdominal injury. Extemporised methods were sometimes necessary to apply continuous suction drainage.

Even without actual extemporisations, difficulties in transfusions were inevitable under field conditions. Lieut-Colonel J. O. Smith writing of the Tobruk battle, remarked that:

> "whether in a surgical team or not, the medical officer in charge of resuscitation should be technically expert in blood transfusion. It is one thing to perform a transfusion in a public or private hospital, where everything is handed out 'on a plate'. It is quite another thing to give a transfusion rapidly to a patient and without a hitch by the light of a Tilley lamp in a tent, with none of the accepted hospital amenities, surrounded by men who are dying and by others who need blood as soon as it can be given".

At one time at Tobruk six transfusions were being given simultaneously in one ambulance unit while a surgical team was working. It should be added that in these engagements, as in others at later periods, the efficiency of blood transfusions was heightened by having either a small blood bank on hand from another source, or taking blood, say of groups 2 and 4, on the day before casualties are expected.

THE SYRIAN CAMPAIGN

In 1941 when the campaign in Syria began two difficulties were encountered with blood transfusion. The first was the risk of infection; the second the transmission of malaria. Blood for Australian troops was in part supplied from an Allied blood bank in Jerusalem, but a break in the chain of asepsis occurred and severe reactions occurred, three being fatal. The first of the fatal cases showed how infection of stored blood might not be easy to detect, as neither the condition of the soldier, who had an abdominal wound, nor the post-mortem findings roused any suspicion till later when other bottles of the same batch were found to be haemolysed and infected. Examination of a batch showed that haemolysis had occurred, the age of the blood varying from four to eight days. This lysis may have been in part due to a roundabout journey, but most of its lethal qualities were undoubtedly due to infection by coliform organisms and streptococci. After a conference of experts recommendations were adopted for a rigid technique. Major R. Officer was detailed to investigate technical methods, and an account of these was published. Attention was drawn to the necessity for discarding all stored blood with darkened corpuscles or with evidence of haemolysis. Agitation of the bottle would reveal any lysis not at first obvious, but blood should always be allowed to settle for twenty-four hours after the shaking, such as it received in transport. This allowed discoloration of the plasma to be seen. Glucose in the diluting fluid delayed haemolysis perceptibly. It was found that citrated blood should not be stored for more than four days, but blood stored with glucose could be used for ten days. Bottles should be completely filled to obviate splashing. Careful methods were laid down for the cleaning and sterilisation of apparatus by specially trained staff. In some places the local conditions were not favourable for refinements of technique, for instance during the siege of Tobruk, as will shortly be told. It cannot be too clearly emphasised that the most scrupulous technique must be observed if infection is to be avoided in these manoeuvres, which may be simple under ideal conditions but difficult on active service. In the unfortunate Syrian episode nothing was discovered to shake the confidence felt in the Australian apparatus, which continued to function successfully during service in the Middle East. We may diverge from Syria briefly to note that all Services adopted and promulgated similar detailed instructions. Thus the Director of Naval Medical Services circulated in R.A.N. Technical Instruction No. 7 the details of the blood bank technique used in the Red Cross Blood Bank, Walter and Eliza Hall Institute, Royal Melbourne Hospital. These instructions contained rigorous details for cleaning used apparatus, including new and used needles, the assembly of taking and transfusion sets, "Soluvac" bottles, autoclaving of all assemblies and the preparation of "Soluvac" bottles for collection of blood, with further particulars for collection of blood samples and the keeping of records.

The Director-General of Medical Services of the Royal Australian Air Force also published in Medical Technical Instruction No. 10 full details of the preparation, assembly, and use of the standard sets, with diagrams

of essential parts, such as the stoppers and associated fittings. The coordination of equipment and of the methods of its use throughout the Services was of the highest value and simplified greatly the carrying out of these important clinical procedures.

Returning to the Syrian campaign, the problem of transmission of malaria arose seriously for the first time among Australian forces in the Middle East. Brigadier N. H. Fairley, then Consulting Physician to the A.I.F., issued a grave warning of the danger, as Syria was in parts a highly malarious country, where malignant malaria was common in the late summer. For this reason stored blood was at first thought preferable in Syria, but for a time confidence in stored blood was impaired by a few unfortunate happenings. However where blood was taken from volunteers on the spot, care was taken to ensure as far as possible that donors were not carrying malaria. If time permitted a donor exposed to the risk of malaria was given 10 grains of quinine or 0.2 gramme of atebrin 6 to 12 hours before blood was collected. The recipient was given 0.2 gramme atebrin at once or 10 grains of quinine by mouth or intravenous drip. If the donor was found to have malaria a standard course was given to the recipient. In all instances a follow-up course of 10 grains of quinine or 0.3 gramme of atebrin in divided doses twice a week was given for two weeks.

Brigadier W. A. Hailes remarked that:

"everyone who has seen the consequence of infected blood is emphatic that he would sooner risk infection with malaria than blood contaminated with pathogenic bacteria —there have been no adverse reports when the blood has been stored only 36 hours. Field units or base hospitals storing blood have not the facilities of research institutes and large blood banks. Our more recent experience and evidence tends to emphasise our outspoken preference for a decentralised as opposed to a centralised blood service. Adequate supplies of wet serum will help materially to solve our difficulties".

It was later estimated that the use of serum in Syria reduced the call for blood by one-third.

TOBRUK FORTRESS

In April 1941 difficult problems of supply faced the troops beleaguered in Tobruk. The 2/4th Australian General Hospital carried out transfusion work there under supervision of Major Rudd, the pathologist. Here blood had perforce to be collected "on the hoof", both from patients and members of the headquarters staff. It was found preferable to use blood within a few hours of collection. Serum was also used with success in emergencies and to counter the shock and depleted blood volume of burns.

The value of serum for burns treated even under emergency conditions was well illustrated when H.M.A.S. *Vampire* was sunk while on service in the Mediterranean. Serum in "Soluvac" bottles was used on some extensively burnt men with good results, though some of the survivors suffered also from immersion and contact with oil fuel. Naval medical officers have also stressed the importance of adequate training of sick berth staff in the administration and even preparation of plasma at short notice.

Considerable difficulties arose in Tobruk in preventing contamination of apparatus and materials. No running water was available for washing flasks and tubing. It was found too, if free exit of air from the flask was impeded while in the autoclave, that sterilisation might be defective. Contamination could also occur by inrushing air during the sucking of citrate solution.

EL ALAMEIN

In 1942 after the departure of the 6th and 7th Divisions of the A.I.F. for the Pacific areas the 9th Division took part in the battle of El Alamein. The blood requirements of this division in the desert were mainly met by the British Blood Transfusion Service. This very efficient organisation used standard British pattern apparatus and refrigerator vans powered by petrol engines. Donors from troops in Cairo supplied blood which was sent by air to forward areas and distributed by refrigerated trucks or by air in insulated boxes packed with ice. Glucose solution in saline was also supplied with or without 0.5 per cent sulphanilamide. Blood was also stored in refrigerators specially installed for the purpose in the main dressing stations of the Australian field ambulances. The resuscitation team built up a stock during the twenty-four hours preceding an attack.

Blood, serum and dried plasma were all available during this action, and in forward areas were used in roughly comparable quantities. Supplies of serum arrived from Australia in good order, with no faulty assembly or contamination. Some deposit of denatured protein was found, but this was not excessive, and was usually entirely removed by filtration. Occasionally some slight turbidity persisted but it was not of consequence. The serum kept well, even if not in cold storage. The British oversea pattern equipment was largely used. It was very satisfactory, though the filters tended to block after passing about two pints, and had to be replaced.

A noticeable feature of the transfusions at this time was the frequency of reactions. A few patients had mild rigors soon after having serum, especially those with burns. Blood also caused reactions; in some medical units these were relatively few and mild, and controlled by slowing the rate of drip. In others the reaction rates were much higher, even up to or above 50 per cent, owing apparently to apparatus and solutions. By intensive care in cleaning the bottles and tubing, and cutting rubber tubing at intervals to test cleanliness, these troubles abated. It may be remarked that dust and flies were serious pests during these battles. Not all men would stand a rapid rate well, and more reactions occurred after transfusions given in the middle of the day. Jaundice occurred after a certain number, especially if a large volume of blood was given, and more particularly if the blood was some days old. Some blood was drawn from men with anxiety states held in rest camps: this blood was used within forty-eight hours. Members of the Royal Australian Air Force concerned in this campaign were not slow in remarking and recording the importance of the arrangement by which the air evacuation centre and blood bank were sited by the army near the most forward airfield.

Resterilisation of sets was best done at base units or by the transfusion service.

A good summary of the resuscitation work done in the 2/8th Field Ambulance during the battle of El Alamein was compiled by Major R. Formby. He based resuscitation methods on the compensatory mechanism in shock, which in healthy young men would allow for a rapid loss of over a litre of blood without circulatory failure. All the patient's blood is then used in a reduced vascular field, but if the amount of this sudden loss rises to 1,500 c.cm. compensation cannot be made, and the familiar effects of reduced blood volume, and lowered rate of blood flow with the associated anoxia are seen. Formby classified the severity of traumatic shock by the blood pressure, a rough rule of thumb measure subject to fallacy, but of some value if applied to patients with comparable conditions.

The term "severe" shock was used if the systolic blood pressure was less than 60 millimetres of mercury, and "medium" shock if the blood pressure was between 60 and 90 millimetres in patients presenting the clinical picture of shock. In this series it was assumed that the "severely" shocked patients had lost at least 2,500 c.cm. of their blood volume, and those with a "medium" degree of shock at least 2,000 c.cm. The former were treated by being given a litre of serum as rapidly as possible, the average time being 20 minutes. Where individual attention was possible the time was reduced to 10 to 15 minutes. Another litre of fluid was then given, half serum and half blood at a reduced rate, 60 minutes being taken, unless the degree of response to the first litre was not satisfactory, in which case the rate was increased. A satisfactory response was judged to be a striking improvement in the clinical condition and a rise in the systolic blood pressure to 90 or 100. This result was aimed at, and when it had been attained the rate of further transfusion was reduced to a rapid drip. A satisfactory response to the second litre of fluid was considered to be the attainment of a good colour by the patient with normal respiration and systolic blood pressures of 110 to 120. A third litre was then started using blood, which was administered at a rapid rate if the response was not satisfactory up to that point, the rate being reduced to a slow drip as soon as the blood pressure reached 110 millimetres of mercury. A patient was considered to be fully resuscitated when the blood pressure had remained steady at 120 for one hour. He was then regarded as being at the ideal period for operation. There were certain exceptions to this generalisation. Men suffering severe pain, with uncontrollable bleeding or with a tourniquet on a limb which it was hoped to save, were operated on as early as possible after a blood pressure of 100 had been attained. During the pre-operative waiting period transfusion was continued to replace the slow loss from wounded tissues. Immediately after operation a few hundred c.cm. of blood were given rapidly to restore the blood pressure to 120 c.cm. and an endeavour was made to maintain this level for half an hour after operation before transfusion was stopped. The object in this routine was first to overcome stagnant anoxia arising from lowered blood volume and thus to mobilise all available haemoglobin. Speed was a necessary

factor and this could be more simply attained by the use of serum. Either reconstituted "dry" serum or "wet" serum was used interchangeably with equally good results.

The patients classified as suffering from "medium shock" were assumed to have lost two litres of their blood volume. They were given serum rapidly till the blood pressure reached 100-110, and thereafter blood and serum by slow drip for the remainder of the period before operation.

Blood was further transfused during and after operation at a rate governed by the blood lost at operation and the subsequent blood pressure readings. The average time taken by these transfusions was fifteen minutes for the first half litre, thirty minutes for the next half, and one to three hours thereafter for a litre of blood. One-quarter of the men in this category had abdominal wounds; they responded as satisfactorily as others, but if more extensive operations were required, as they sometimes were, more fluid was administered.

In addition to the above categories Formby also distinguished between patients with "mild" shock in which the blood pressure was over 90, those who were suffering from continued bleeding, who are mentioned above, and those who were moribund. The blood loss in "mild" states of shock was estimated at 1,500 c.cm., and the type of resuscitation was modified accordingly, it being recognised that blood loss of over one litre demands active treatment.

In judging the results of these methods, we must realise that all the patients were physically and mentally fit and young, very few being over 32 years of age. In two months 1,600 battle casualties were treated at this main dressing station; 252 of these were admitted to the resuscitation ward, and 150 needed transfusion. Only 4 of the men in this series had a complicating medical disease. The weather was warm to hot, and the nights, though cold, were not freezing. Dust was always present, either borne on the wind or hanging over the battlefield in a heavy cloud during the entire period. Most of the patients were admitted to hospital within 8 to 12 hours of wounding during active fighting, and during quieter periods within 4 hours. Later when the front moved forward some men reached the main dressing station only 18 to 24 hours after being wounded. Two surgical teams were available, and the casualty clearing station was distant only 4 hours' journey on a good road. The usual procedure was followed of a thorough examination with investigation of wounds on admission. The degree of shock was estimated, and morphine given as required. For the guidance of the orderlies three rates of administrations were recognised: fast (half a litre in 5-8 minutes), medium (half a litre in 20-30 minutes), and slow (half a litre in 60-90 minutes). Blood pressure readings were taken as frequently as possible. Only in 8 cases was it necessary to use a cannula; the intravenous needle was put into a vein in the cubital fossa with the arm lying along the side on the stretcher. Patients were held for 8 to 10 days if necessary. Of 252 patients 26 died.

It is perhaps not surprising that with multiple transfusions given usually at a rapid rate febrile reactions were common. They occurred in about

half the cases. Shivering accompanied a rise in temperature, which reached 102° to 104°F. Slight headache, giddiness and tightness in the chest were frequent, but never backache. The blood pressure usually rose, sometimes to 150 millimetres. Vomiting occurred in about one-third of the cases. These reactions usually began soon after transfusion started. While supplies were abundant the bottle of blood or serum was changed when a reaction began, but later this was done only if reaction or shock was severe. As a rule symptoms disappeared in about twenty minutes unless a slow drip was continued, when they subsided slowly. Twenty patients had more than one reaction during transfusion; these men had slight cyanosis as well as the other signs, but this was quickly relieved by oxygen. An urticarial rash was seen in two only. All blood used was group O, and was transported 200 miles. On arrival it was thoroughly stirred up, and no blood was used which showed more than a trace of haemolysis after settling. Many bottles were sent back to base for testing, but no infection was found.

The results from resuscitation carried out on the described system were very good. The reactions were upsetting to the patients, but in no instance did they do any harm. This experience shows how it is possible to reduce resuscitation to system in a forward dressing station, and to achieve success even if continuous individual attention was not always possible.

The advantages of having adequate supplies of transfusion fluids at hand during this action were very great. The supply of Australian saline and glucose solutions ran short, but the British transfusion service supplied all that was needed. The larger quantities of blood and serum used reflected the experience of all surgeons, that it is important to give enough, and to give it soon, because the effect of the second transfusion is often not so good as that of the first, owing to stopping the infusion too soon. On numbers of occasions the continuation of a transfusion during a patient's transport by ambulance was of great value.

IN JAPANESE PRISON CAMPS

When the Australian forces in Malaya were forced with other Allies to capitulate to the Japanese the members of the medical units were scattered from Singapore to Japan. Even in the more settled areas on Singapore Island facilities were very limited, but in many of the working camps in Burma and Thailand they were almost non-existent. Blood transfusion could be used only where there was reasonable opportunity for aseptic manipulations.

In Burma during one severe outbreak of dysentery transfusion was tried, but severe reactions occurred among the debilitated patients, and some did not survive long afterwards. Later in Thailand the technique of using defibrinated blood was followed, after a method introduced by Major Reed, R.A.M.C., and developed by Major J. Markowitz, R.A.M.C. Blood was received in a sterile container and stirred during the taking and for five or six minutes afterwards with a spatula or a bunch of slivers of bamboo. After filtering through at least sixteen layers of gauze it was given by a funnel and tube. Occasionally a syringe was used for adminis-

tration. Major W. E. Fisher, A.A.M.C., after favourable experiences with this method established a clinic in Nakom Paton, a vast hospital compound at the Thailand terminal of the railway constructed by the Japanese with such suffering and loss of life. Here a medical officer was in charge, but lay patients and officers and a few orderlies were trained and attained a high degree of skill. In this camp Lieut-Colonel A. E. Coates, A.A.M.C., who was in charge, has described the ingenious extemporisations by which distilled water was made and the necessary pieces of apparatus were produced out of mess tins and the like. Hundreds of transfusions were given by this method in camps along the railway line with excellent results. Reactions were very rare, and 450 to 600 c.cm. could be safely given even if a rapid rate was used. Care was taken to prevent the collection of any protein residue in the tubing, and the apparatus was simple to use and clean. At Nakom Paton 1,450 transfusions were given in fourteen months for many conditions, including anaemia, chronic malaria, dysentery, debility, and chronic so-called "tropical" ulcer. Bombing attacks on the camps also produced casualties needing transfusion. Citrate became available at this camp, and numbers of transfusions of citrated blood were also given. One party of men from a local working camp was specially in need of blood: half of the men had haemoglobin percentages under 50, not a few being as low as 20 or 30. Repeated transfusions, up to four or more, were given with excellent results. The poor condition of most of the men made it difficult to select donors. As a rule no man was allowed to give blood if his haemoglobin was below 85 per cent, but in times of stress figures below this were accepted. Attempts were made to exclude donors with malaria, a condition by no means easy to fulfil.

At Tamarkan Lieut-Colonel E. E. Dunlop described a transfusion service organised by Captain C. J. Van Boxtel, a Dutch chemist attached to the Australian Medical Services, who with Lieutenant W. Roberts, R.A.N., acquired great skill in this work. Ninety per cent of the men so treated here had gross malnutrition associated with anaemia, or were anaemic as the result of blackwater fever or haemorrhage from various causes. Grouping was carried out by the use of test serum derived from the blood of Australian volunteers whose blood types were known. Cross agglutination tests were almost always done. Only impure citrate of soda was available at first, and the defibrination method was used, but later citrated blood was given. A small needle of 1/2 to 3/4 millimetre was used, and the blood was run in at a slow rate. If more than 400 c.cm. was given to some of these debilitated men in less than an hour reactions were prone to occur: the difference between this experience and that of medical officers treating strong fit men in the Middle East will be noted. Reactions were minimised also by the use of distilled water for cleaning the apparatus with the use of an extemporised still. One of the most spectacular results was the recovery of a man with a haemoglobin percentage below 20, after 130 ounces of blood given within three days.

In all, thousands of transfusion were given during these years in Malaya, Burma and Thailand, and in spite of difficulties in material, technical

methods and selection of donors, many of whom were not at all well themselves, illnesses were shortened and lives saved.

When the day of liberation came the medical services specially sent from Australia to care for the men of the 8th Division were able to rescue many men near to death by timely transfusions. For example at Kuching desperately ill men needed resuscitation and 40 pints of blood were sent from the 2/4th Australian General Hospital at Labuan on a few hours notice. In the words of Major Howard H. Eddey they were thus "rescued from the grave".

PACIFIC CAMPAIGNS

Early experiences with campaign conditions in New Guinea in 1942 showed that special arrangements for the supply of stored blood were necessary. Blood and serum preparation units had been established in each capital city, at first under the aegis of the Red Cross Society, and later as army units working in conjunction with Red Cross. A team of haematologists and pathologists not only advised as to methods and organisation, but carried out research on many important subjects which are touched on later in this account. Blood was sent by air from Sydney to Port Moresby in New Guinea in specially designed cork-lined insulated ice boxes. Blood from universal donors was collected into the standard "Soluvac" flask, using the Medical Research Committee's saline citrate anti-coagulant. The bottles were filled to capacity to save the corpuscles from damage from shaking, and sealed with wax and cellophane. Later the blood-collecting centre was perforce shifted farther north, to cope with the spreading forces, and in the latter stages of the Pacific war was stationed at Morotai. Serum was supplied in addition. It was particularly necessary for naval ships, as many casualties were due to suicide Japanese bombers. Following a *Kamikaze* attack on H.M.A.S. *Australia* in December 1944, in which 96 casualties occurred, causing 30 deaths, the value of fluid replacement was striking. Fluid was administered by mouth, and sometimes *per rectum,* in addition to plasma given intravenously. Surgeon-Commander J. M. Flattery records that the medical officers worked continuously for fifteen hours. When the Royal Navy arrived in the Pacific, the ships and shore establishments were also supplied. By the time the end of the war came great expansions had taken place in the organisation, and large numbers of volunteer donors were sought and provided.

Transport of blood by air was necessary in the islands on account of the distance and the difficulties of terrain. Even after blood had been landed at airfields in good condition its distribution was often troublesome, involving journeys over rough jungle roads only fit for jeeps. High priority of air transport was arranged by Air Vice-Marshal T. E. V. Hurley, Director-General of Medical Services of the R.A.A.F. Blood collected at Sydney in the evening of Day 1 reached Port Moresby on the afternoon of Day 2, and often was actually being used at main dressing stations on Day 3. It was found that blood would last up to a week if ideal conditions of transport and refrigeration could be maintained. Ideal conditions were,

however, almost impossible to obtain, and haemolysis tended to appear quite early and to limit the life of the stored blood. Further, the long distances, shortage of transport in the air and on the ground, and the ever changing tide of battle all limited the usefulness of stored blood. Serum proved to be of more practical value than blood for immediate use for battle casualties and was successfully used in great quantities. The heat and trying conditions were also conducive to dehydration, especially in severe diseases like toxic varieties of dysentery, typhus and malignant malaria, and therefore large quantities of glucose-saline were needed for intravenous use. The improvement in many of these patients was dramatic, and many lives were thus saved.

PORT MORESBY AREA

The 2/9th A.G.H., the first Australian general hospital to work in the New Guinea campaigns received large numbers of patients from forward units who had travelled over a long and trying line of communication.

Lieut-Colonel S. W. Williams, in describing the transfusion work done there, divided the period into three phases. During the first phase in the later part of 1942 indirect transfusion was carried out when required, donors being used from troops who had not been outside the relatively malaria-free Port Moresby area. The standard flask was used with 100 millilitres of 4 per cent sodium citrate to 900 millilitres of blood. No storage was needed, as the operating theatre was not ready for use at this time. Two cases of tetanus were seen; continuous liquid serum and glucose-saline given for over a week helped to produce a good result. In the second phase men with serious wounds were admitted to hospital from the Owen Stanley-Buna battlefields, and a special blood centre was organised by Major C. Fortune, who had great previous experience in the centre in Perth. Stored blood was not kept over seven days, and precautions were taken to exclude donors with malaria. In the use of glucose-saline close inspection of each flask was necessary, as contamination by moulds was then common.

The third phase opened with the institution of the air-borne service of blood from Sydney. Ten to twenty litres arrived each week, practically always in excellent condition, except when transport delays had taken place. Tests showed that practically every bottle was sterile even when ten days old.

Eleven men with blackwater fever were treated during this period. Great care was taken in direct typing both with stored and local blood. Only one severe reaction occurred, but no harm followed. A special room was provided for the blood bank, staffed by selected members of the nursing service who could carry out all details of the work. The need for holding large quantities of liquid serum as well as stored blood at a forward base was seen in one unfortunate accident during a movement of troops by air from Moresby to the Ramu Valley. A fully loaded Liberator bomber crashed among the motor vehicles of a convoy, killing many and causing severe wounds and burns in over 100 men. Though

the mortality was high amongst these, there were numbers who were saved by immediate fluid replacement.

In the landing on "Red Beach" some miles north of Lae the 2/3rd Casualty Clearing Station accompanied the 9th Division at the initial landing, but remained at Red Beach when the division pressed on towards Lae. This unit was unable to obtain stored blood before arriving at the landing beach. Its heavy section was delayed by enemy action on the convoy, but the bleeding of donors was begun in less than twenty-four hours after the light section reached the beach head. An air raid produced some severe casualties, and, even with the help of a neighbouring field ambulance, the stock of blood ready was insufficient to meet demands. In any case there were drawbacks to the procedure of using men bound for forward positions as donors. As military operations progressed patients were transported both by land and sea, the latter by night to avoid enemy action. This necessitated the resuscitation of severely ill men in a blacked-out tent by the light of kerosene lamps. However, more surgery and transfusion were being done at advanced and main dressing stations, and at the clearing station most intravenous therapy was done after operation. During this phase pooled serum had to be sent forward to the forward stations, together with such supplies of stored blood as came forward. This latter was but small in amount, arriving from Buna in ice boxes, but only irregularly, owing to the lack of an organised delivery service. It was found that the more seriously a man was wounded, the more he needed blood. Injuries such as compound fractures of the lower limbs, and others involving great shock and loss of blood demanded three or four litres of blood during the pre- and post-operative periods. Pooled serum was used, but could not entirely substitute for blood. One litre of blood was usually given in fifteen minutes in the early stages of treatment. Cleaning and sterilising apparatus occupied one orderly all day; it was necessary to use physiological fluids for cleaning the "Soluvac" apparatus to ensure absence of pyrogens. Only few reactions were noted. Major D. Duffy, in reporting thus on this work, remarked also that the standard Australian set was found to be preferable to the American supplies of dried plasma. The "Soluvac" filter then in use gave some trouble in its fine mesh blocking, but the apparatus worked well and the greater volume of the bottle saved the more frequent changes of the American pattern. The latter, however, had features of packing and design which fitted it admirably for use in forward areas. The lack of a drip chamber made it difficult to judge the rate of flow, which was often rather slow, and no cannula was packed with the apparatus.

The blocking of filters mentioned above was an occasional trouble not altogether avoidable when stored blood was used. A modification of the filter gave improved performance, but it was difficult to avoid blockage entirely when this was due to changes in stored blood, such as aggregation of cells, disintegration of leucocytes and consequent sedimentation.

The use of transfusion in amphibious landings was illustrated in New Guinea in the 9th Division attack on Lae in 1943. Major G. Newman

Morris has described the experience of one surgical team. Two standard transfusion panniers were included in the equipment, and the contents of each of these were divided into two boxes, in order to reduce each load to 40 lbs. suitable for native carriers, and to provide all essentials in each package. Half the "Soluvacs" containing saline were replaced by bottles of human serum. The headquarters of the field ambulance to which the team was attached also had sufficient serum and giving equipment to supply the needs of the main dressing station when first set up, saving immediate problems at the landing. The team landed a little over an hour after the first wave of troops, which had met considerable resistance. On arriving at the main dressing station half a mile from the beach, the resuscitation officer was able to begin almost at once on wounded carried thither from the beach by hand. Serum infusions were begun from bottles tied to trees. Operating began two and a half hours after the first landing. No stored blood was available, but donors were obtained from the anti-aircraft regiment in the brigade group near the main dressing station, and four group O4 donors were always kept on the spot. Specially trained orderlies from the field ambulance assisted the resuscitation officer.

In later phases of this campaign two surgical teams worked under much more settled conditions with refrigeration and a small resuscitation ward of three beds. Stored blood was available, but in small amounts only, and twelve or more group O4 donors were obtained daily from troops at the forward base, each giving half a litre. Blood was never kept longer than twenty-four hours. The usual routines for cleaning apparatus were followed as far as possible, and though there were some reactions with all varieties of infusion fluids, no serious trouble was encountered. The three surgeons of the two teams worked two at a time on eight hour shifts, one being responsible for *triage* and resuscitation.

In abdominal injuries serum and glucose saline were used in roughly equal quantity, alternating each fluid occasionally with a litre of blood. As a rule infusion was continued throughout all operations and morphine and "Pentothal" were administered through the same apparatus. The great majority of severely wounded men responded sufficiently to permit operation.

MALARIA AND BLOOD TRANSFUSION

This subject has already been dealt with in the section on malaria, in which the measures taken to minimise the risk of transmitting malaria by transfusion are described. As already pointed out, Brigadier Fairley's first instruction stressed the danger of carrying out blood transfusions in the tropics. The advantages of blood collected in non-malarious areas in Australia from persons never exposed to malarial risks were great, so too were those of serum with its practically unlimited "life" even under poor storage conditions. But the general principle that stored blood or serum should be used could not always be carried out, and experience showed that if the donor showed signs or symptoms of malaria and the recipient was given quinine, it was very rare for untoward signs to appear. What was wanted was some positive evidence of what happened when known malarial blood

was transfused and "covered" by the administration of a standard course of treatment to the recipient. When the Malarial Research Unit was established, Fairley had this subject investigated by Major R. Officer, Major Tonge and Captain Freeman at the 2/2nd Australian General Hospital. They found that, if blood containing a sufficient number of malarial parasites to be easily recognised in a thick blood film was transfused into a patient who was immediately given a routine anti-malarial course of treatment, few or no symptoms occurred. A single course of treatment was sufficient to prevent recurrences, as is the rule with trophozoite-induced malaria, in contrast to the natural sporozoite-induced disease in which exo-erythrocytic forms of the parasite are unassailable to the usual drugs.

This finding confirmed other observations already made in the field. One such series was published by Major P. Braithwaite from a forward surgical unit in the highly malarious Aitape-Wewak area of New Guinea. In this series the average quantity of blood given to each patient was 1,400 c.cm. when local donors were bled, and 1,000 c.cm. when stored blood was used. All patients with malaria had the malignant tertian form; occasionally the benign tertian type was also present. Stored blood from Sydney was tried on eight patients, but all of them had rigors. This was not surprising as the blood had to be sent on from a hospital at Aitape, and this involved a drive of 7 miles over a rough road, an hour's journey by air and an hour's porterage by natives. The method of selecting donors who had not had malaria was unpractical as almost all troops in the area had suppressed malaria. Premedication of donors was not always possible, owing to the urgency of circumstances. In any case the mean level of atebrin in the plasma of 100 men who had taken 0.1 gramme atebrin daily for over six weeks was 21 microgrammes per litre, and in a group receiving 0.2 gramme daily it was 42 microgrammes. In this latter group premedication by 0.3 gramme atebrin would raise the plasma atebrin content to 57 and 47 microgrammes after two and four hours respectively. Even these levels, however, have been found experimentally to be insufficient to prevent transmission of malaria if the blood contained asexual parasites. The giving of atebrin to the recipients of transfusion was tried practically, and as a routine all wounded men received 0.5 gramme atebrin on admission and a similar dose next morning.

The same routine was followed before and after transfusion. The results from these methods were satisfactory, but even at a time when the troops were receiving 0.2 gramme atebrin daily the weekly malaria rate averaged 0.4 per thousand, and during one month when 9 transfusions were given from local donors one patient contracted overt malaria. In June-July 1945 the average weekly malarial rate was 22 per thousand, and out of 40 apparently well officers and men selected at random 14 showed parasites in a single slide. A further series of 8 patients given transfusions all contracted malaria. Braithwaite points out that the blood of the patient in such circumstances is often more potentially malarious than that of the donor.

Accordingly the routine was established of giving the following anti-malarial course to each patient after transfusion: 1st, 2nd and 3rd days 40 grains quinine daily, 4th and 5th days 0.6 gramme atebrin daily, 6th to 9th days 0.4 gramme atebrin daily and 10th to 12th days 0.2 gramme atebrin and 0.02 gramme plasmoquine daily. This method gave very satisfactory results, the patients did not contract overt malaria and improved in general health.

At the 2/7th A.G.H., a 1,200 bed hospital stationed at Lae in New Guinea, a local donor service was established in May 1945 because increasing demands for blood in other areas made supply of stored blood from Sydney impracticable. The Lae base area was then under good malarial control and a panel of 200 donors was easily obtained, available at short notice. A dust-proof room was used as the bleeding room of the blood bank, and separate rooms were provided for preparation. Here, with a local malarial rate of 0.8 per thousand per week and with all troops taking 0.1 gramme of atebrin daily as a suppressive, few donors were found to have parasites in a blood film. Donors were given 0.3 gramme atebrin 4 hours before blood was taken if time permitted, and recipients were given 0.3 gramme atebrin daily for 5 days after the transfusion, and thereafter the usual suppressive dose. The results were most satisfactory.

Lieut-Colonel E. A. Hedberg, in charge of the surgical division of the 2/7th A.G.H., reported very favourable results from transfusions given to patients with chronic sepsis of wounds. Repeated transfusions arrested the steady fall of their blood cells and protein and changed these patients from a listless anaemic state to a much improved general condition in which healing of wounds took place more rapidly. Hookworm infestation also contributed to the anaemia of some of these patients. It was noticed that transfusions were needed more frequently by patients from the Aitape-Wewak area than those from New Britain and Bougainville, where malaria suppression was much more efficient.

While reference is being made to blood transfusion in relation to malarial research the value of direct transfusion must be mentioned.

DIRECT TRANSFUSION

In 1939 Dr Julian Smith, Senior, designed an apparatus for direct blood transfusion which was a most successful modification of one brought back by Major-General Downes from Europe in 1939. This ingenious and precise machine proved most simple and efficient. Julian Smith pointed out that direct transfusion is the method of choice in anaemias and some other blood diseases, and suggested too that some general diseases like ulcerative colitis and chronic sepsis from wounds should be good indications for the use of unmodified blood. Severe loss of blood also called for rapid replacement of whole blood. He presented a series of 300 transfusions carried out by this method, which were marked by a complete absence of reactions.

Early in the war the Army Medical Directorate decided that it was undesirable to have more than one official method of transfusion, and that

the indirect method was of greater value. Certainly this method was more flexible and permitted storage of blood, and also provided a single means of supplying any replacement fluid. Work in the Malaria Research Unit at Cairns showed, however, that for certain purposes, such as the rapid transference of unaltered blood from donor to recipient, as was necessary in some experimental work in malarial transmission, the Julian Smith machine was admirable. A simple stripper device was also described by E. H. Hipsley which aided gravity and might be used as a substitute for a rotary pump.

Direct transfusion with the Julian Smith pump was used on numbers of occasions in the services and with excellent results and no mechanical difficulties. For example, Surgeon-Lieutenant J. S. Guest, R.A.N., and Surgeon-Lieutenant K. C. Bradley, R.A.N., reported cases in which massive transfusion was given simply and safely by this method, and with an absence of any "speed shock". There is no doubt that this method has a definite place in the technique of blood transfusion.

TRANSFUSION SERVICES IN AUSTRALIA

The base organisations connected with blood storage and transfusion in Australia have been associated since their inception in 1929 with the Australian Red Cross Society. Dr E. L. Cooper when Medical Superintendent of Royal Melbourne Hospital first suggested in 1929 the formation of a blood transfusion service with voluntary donors. The pioneer service in Australia was begun by the Victorian Branch of the Red Cross Society under Dr Lucy Bryce and this was followed by the establishment of similar organisations in Perth and Brisbane. In other States civilians needing transfusion were served by individual hospitals or separate donor groups. Following pioneer work on blood storage at the Royal Prince Alfred Hospital in Sydney, and the Walter and Eliza Hall Institute in Melbourne the first Australian blood bank was established in Melbourne. The advent of war in 1939 brought rapid expansion of Red Cross services in all States, and subsequently army blood and serum preparation units were established in all States except Tasmania, where Red Cross provided a civilian service. The army supplied medical officers and some auxiliary staff for these units, while Red Cross undertook organisation of accommodation, panels of donors, equipment and other helpers. Normal civilian needs were met through Red Cross organisations, and the combined services provided for all needs of the fighting Services and possible civilian needs in case of enemy attack on Australia. This organisation was so designed as to simplify reversion to the Red Cross Society after the end of the war.

A National Blood Transfusion Service Committee was then set up, responsible to the Medical Services Committee of the Australian Red Cross Society, which included the senior officers of the three armed Services. A technical sub-committee was appointed to keep in touch with recent scientific advances, and experts were also sent overseas for purposes of special investigation or study. The aims of the transfusion services

during the years of war were given by the President of the A.R.C.S., Sir John Newman Morris, as follows:

1. Selection of blood from donors with high-titre serum (Anti-A and Anti-B) for grouping tests.
2. Establishment of panels of "Rh-negative" donors through cooperation of the medical profession, and provision of anti-Rh serum.
3. Supply of special products, red cell suspensions and concentrated serum for therapeutic experiment in clinical schools.
4. Carrying out and publication of original investigations.
5. Supply of individual donors to practitioners.
6. Supply of group O blood from end of 1942 for air transport from Queensland and New South Wales to Australia and Allied military hospitals in the South-West Pacific Area.
7. Establishment of blood banks in civil hospitals in many Australian towns, and maintenance of stocks of serum. Special transport facilities were given if needed.
8. Supply of serum to naval and mercantile marine units under specified conditions, and to the Royal Navy units operating in the Pacific Zone.

Fortunately no widespread need for infusion fluids arose in Australia because of enemy action, but the value of an efficient organisation was well evidenced in 1944 when serious bush fires swept part of Victoria. Five hundred litres of serum were distributed with sterilised giving sets to country hospitals in preparation for emergencies due to burning accidents which were luckily few in number.

A considerable contribution was made to the transfusion services by many volunteer workers all over Australia, including many medical men and women, both those in active practice and others in retirement. Some of the most important work related to the preparation of serum and plasma.

PREPARATION, PRESERVATION AND USE OF WET SERUM

The first reference in the literature to the use of human plasma is to be found in a letter to the Editor of the *British Medical Journal* 9th March 1918.

Transfusion of Plasma

"Sir, I have been reading with interest recent articles in the Journal on blood transfusion in casualty clearing stations. Apparently one of the chief troubles is the question whether or not the recipient's plasma will haemolyse the corpuscles of the donor.

Surely this difficulty might be avoided by not transfusing the corpuscles at all, but only citrated plasma, which would be easy to keep and easy to give. There is abundant clinical and experimental evidence that it is not the corpuscles that are wanted, but the ideal fluid for keeping blood pressure at its proper level, and the apparent abundance of blood is, no doubt, due to its permanent value in this respect, and to its food value. A man apparently dying from haemorrhage is not dying from lack of haemoglobin else severe cases of anaemia would die long before they do, but from draining away of fluid resulting in devitalisation and low blood pressure.

May I at least recommend a trial of this method, controlled, let us say, by an equal number of whole blood transfusions and an equal number of gum acacia (not less than 6 per cent) cases?

Gordon R. Ward,
Capt. R.A.M.C. (S.R.)."



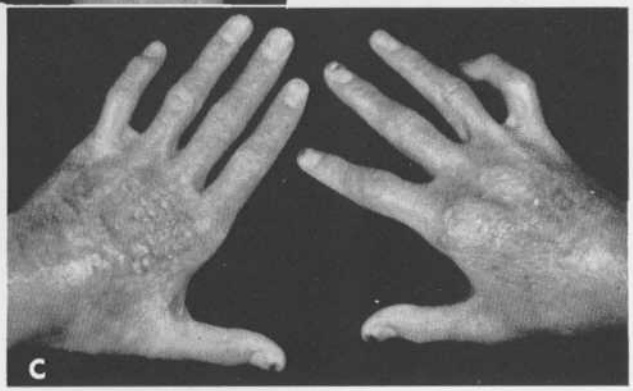


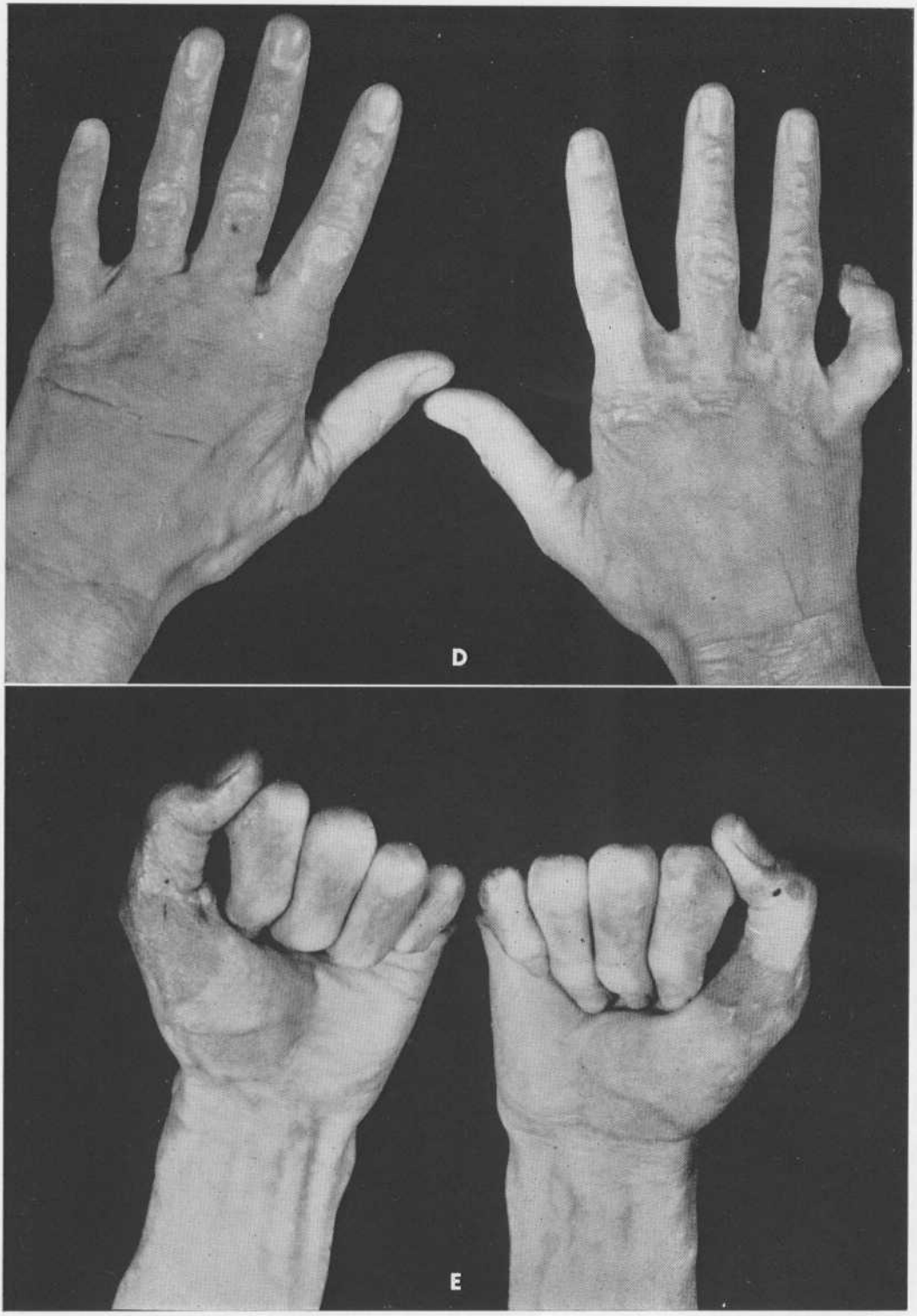
Types of skin graft for burnt hands.

(B. K. Rank)

(a) Severe burns of both hands, back and front.

(b) and (c) Result of early healing by palliative skin grafts. There is gross limitation of flexion through skin loss and scarring on the dorsum of the hands.





Types of skin graft for burnt hands.
(d) and (e) Final result after scar excision and skin replacement.

It was really not until the threat of the 1939-1945 war that large scale production and use of serum were undertaken. The rationale for the use of serum or plasma as stated by Captain Ward—"the draining away of fluid resulting in devitalisation and low blood pressure"—was substantiated during the inter-war years by an abundance of clinical and experimental evidence. It was recognised that a reduction of the circulating blood volume is a characteristic of shock whether the shock follows injury, haemorrhage, surgical operations or burns. The fundamental therapy was therefore directed to the prevention of a further reduction of the blood volume and the restoration of any reduction to normal levels.

BLOOD SUBSTITUTES

Ideally, the particular constituent of blood which has been lost from the circulation should be replaced, but other factors, such as availability and stability of the fluid to be used have to be considered. Whole blood is not a stable substance and is not always readily available in spite of the advances made in the storage of blood. It was necessary therefore to seek other substitutes.

It is desirable that some substance of animal or synthetic origin be used, but before any particular substance is acceptable it must fulfil the following criteria of suitability:

(1) The solution must be retained within the circulation of the recipient and must not pass out of the circulation through the capillaries. Therefore the molecules must be of relatively large size.
(2) The substance must not of itself be toxic to the patient. Gum acacia is toxic in so far as patients for whom it has been used have shown signs of pulmonary thrombosis and other respiratory disturbances.
(3) The substance must not be antigenic in any way whatsoever. Development of sensitivity would render it unsuitable.

During the war years nothing was found which fulfilled these conditions nearly as well as serum or plasma. A number of substances were investigated in different countries, before and during the war, including glucose, saline, pectin, isinglass, gelatin, oxidised cotton and dextran. Bovine albumin seemed more promising, but attempts to use it were frustrated because it could not be purified to the extent of rendering it non-antigenic.

SERUM AND PLASMA

But though no synthetic substance could be found, derivatives of blood proved very satisfactory and became the basis of resuscitation therapy. During the 1939-1945 war in England both serum and plasma have been used, but in Australia serum alone was used. The Americans used plasma extensively, and during the later years of the war fractionated human plasma into several different components. Albumin, the last fraction that was obtained, was used most successfully for blood volume restoration.

However, in Australia no attempt was made to fractionate human plasma and the choice lay between plasma and serum.

There was considerable controversy as to their relative merits and in making the choice between the two the following points had to be considered:

i. The therapeutic value of the product itself from the point of view of the resuscitation of the patient.
ii. The ease with which the substance is prepared and processed.
iii. The absence of toxic products.

The following table compares the two substances:

Plasma	Serum
Allegedly less toxic	Allegedly more toxic
Filtered with difficulty	Easily filtered
Protein concentration 4.5-5.0 grammes %	Protein concentration 6.5-7.0 grammes %
Clots form with age	More stable
Contains fibrinogen	Lacks fibrinogen

From the therapeutic point of view war experience showed that there was no difference between serum and plasma—they are both equally efficacious in restoring blood volume. At first it appeared on experimental grounds that replacement of blood volume and resuscitation were much more efficiently produced by the use of plasma and its manufacture was therefore undertaken in America and England. In the original investigations animals were bled to the point of shock. Retransfusion of the blood was found to restore the animal to normal condition. Replacement of the removed blood with an equivalent volume of plasma also restored the animal to normal condition, but unfortunately the administration of serum to the animal did not produce the desired effect. Instead, the animal suffered respiratory disturbances and in some cases a fatal fall of blood pressure (Brodie phenomenon). Serum thus in the earlier days gained the reputation of being more toxic than plasma.

As time went on, however, much work was carried out on the toxicity of serum. At various times it was alleged that there were three forms of toxic substances which may be present in serum:

(1) A vasoconstricting substance which also stimulates smooth muscle.
(2) An adenyl group of compounds.
(3) An unidentified substance which produces a fall of blood pressure, especially in the cat.

It was demonstrated in Melbourne that freshly prepared human serum contains an amount of this third substance. In man such serum may produce a phenomenon similar to but less marked than the Brodie phenomenon of animals. Because blood, rich in platelets prior to clotting, was most toxic in this respect, it was concluded that the toxic substance was derived from the breakdown of platelets during the process of clotting.

It was also found that the toxicity of serum disappears entirely when the serum is matured by storage for a period of three to four months.

Serum as first prepared was filtered and plasma was not filtered. Probably some of the toxicity of the early serum was due to the organic and inorganic impurities in the filter pads. It is now generally recognised, however, that serum is non-toxic if allowed to mature and if filtered through chemically pure filter pads.

One factor in favour of serum, and this was probably the major factor in its being preferred to plasma, was that serum was very readily filtered. Plasma, on the other hand, was filtered only with great difficulty, and calcium salts present in the filter pads were found to cause clotting of plasma. A technique to overcome this difficulty was devised in England by Brigadier Whitby, but the process was expensive, laborious and not altogether practicable for large scale work. Australian workers felt that if a blood substitute was not filtered the risk of infection was greatly increased, and they were confident that by manufacturing and supplying serum they were providing a product in which the risks of contamination were very small. Other differences between serum and plasma should also be stated.

Plasma has a lower protein content than has serum, because of the large amount of anti-coagulant solution that must be used in its preparation. Liquid serum is much more stable than liquid plasma. If it is stored in the liquid state, large clots may form in plasma. Serum lacks the fibrinogen which is present in plasma and it has been alleged that this deficiency is a disadvantage. It has been claimed that fibrinogen is of value because of the osmotic force it exerts and also because of its nutritive value.

However, the osmotic force exerted by the fibrinogen of plasma is not of great importance, since the osmotic pressure of a fluid is proportionate to the number of molecules and not the weight of the molecules in the solution.

Protein	Approximate molecular weight	Grammes per 100 mls. Plasma
Fibrinogen	120,000	0.27
Albumin	70,000	4.1
Globulin	150,000	2.7

It can be seen from this table that a solution of fibrinogen of say, 1 per cent concentration will exert only half the osmotic pressure of a 1 per cent solution of albumin. The concentration of albumin in plasma is approximately 15 times the concentration of the fibrinogen. Therefore, the albumin of plasma exerts 30 times as much osmotic pressure as does the fibrinogen. Similarly the globulin exerts 10 times more osmotic pressure than does the fibrinogen in plasma. The absence of fibrinogen in serum, therefore, does not significantly reduce the total osmotic pressure. Further, the higher concentration of albumin and globulin in serum as prepared more than compensates for the loss of osmotic pressure due to the fibrinogen.

Fibrinogen has some nutritive value and it does help to restore the protein content of a patient depleted of his plasma proteins by haemorrhage, shock or burns. But of the three constituents of the plasma proteins fibrinogen is the most rapidly restored as it is rapidly synthesised by the liver. Unless there is severe liver damage the fibrinogen content of plasma is restored within twenty-four hours of its removal.

These arguments may be summarised—preference was shown in Australia for the use of serum largely because serum is easier to prepare than plasma, because there is no difference in the therapeutic results obtained from either product and also because serum is more stable in the liquid form.

WET AND DRY SERUM

Another controversy that was widely discussed was centred on the relative merits of wet and dry serum. It must be admitted that drying of serum does render the product safer from infection and that it makes it a stable product which will not undergo further denaturation if it is sealed in a suitable nitrogenous atmosphere. On the other hand, the dried product is more bulky than the wet product. A given volume of serum is approximately three times as heavy and as bulky in the dry form as it is in the wet. This is due to the fact that distilled water must be carried with the dry serum and to the fact that only about two-thirds of the bottle can be filled with serum prior to drying. Wet serum on the whole was found easier to administer than dry serum. The greatest objection raised to the use of the liquid product was the turbidity that will develop in it. This turbidity cannot be distinguished from the turbidity due to infection. But of all the liquid serum that was prepared in Australia during the war not one bottle was found to be contaminated out of many hundreds that were examined by culture methods. "Merthiolate", an antiseptic, was added to liquid serum and this was, to some extent a guard against contamination.

PREPARATION OF SERUM

Among the many methods of preparing serum two main methods were recognised:

(1) Blood was collected from the donor into a flask and allowed to clot in the flask. The serum surrounding the clot was aspirated, filtered and bottled.

Serum prepared by this method is the most toxic as the platelet content prior to clotting is high. Further, the yield of serum is approximately 40 per cent. The method, however, was suitable for small units and small laboratories.

(2) The other method was to prepare plasma, then to make it clot and process the resultant serum. This was undertaken in two ways:

(a) The blood was originally collected into sodium citrate and placed in the blood bank. If unused for blood transfusions, it was centrifuged and the fibrinogen removed from the plasma, by the addition of calcium chloride. Later kaolin was used to adsorb the fibrinogen.

(b) The more usual method was to prepare serum by collecting blood from the donor for this specific purpose. The blood was collected into a flask containing a solution of oxalate salts and the plasma obtained either by centrifuging the blood or by passing it through a milk separator. A volume of plasma equal to 50 per cent of the volume of the original blood was obtained if a centrifuge was used, whereas a volume of 57 per cent is obtained if a separator was used. Plasma that had been separated by means of a milk separator yielded serum with the lowest toxicity because this plasma had the lowest platelet count. After separation calcium chloride was added to the plasma, the clotting being thus allowed to proceed in the physiological manner. The resulting serum was then filtered by passage through bacteriological filter pads. It was stored for a period of three months to permit maturation and detoxication. After this interval it was again filtered and when bottled was ready for use.

THE TOXICITY OF "MERTHIOLATE"

Immediately after the clotting process "Merthiolate" was added to the serum so as to give a final concentration of 1 in 10,000. The "Merthiolate" acts as a bactericidal and bacteriostatic agent against a wide range of organisms. Unfortunately, it is not universal in its action, some organisms, especially *P. pyocyanea*, being resistant. It was added to serum, however, because it was felt that it offers some protection against infection. The possible toxicity of "Merthiolate" was frequently questioned in the earlier days, and later in the war was again raised in view of the large doses of serum that were being administered. If 10 litres of serum were administered the patient received 1 gramme of "Merthiolate": the question was raised whether this amount would do any harm to the patient.

Experiments showed that the Lethal Dose 50 for mice was 0.045 grammes per kilogram of body weight. Assuming that the Lethal Dose 50 for man is the same as that for mice the Lethal Dose for a man of 8 stone would be 2.25 grammes. In administering 10 litres of serum to such a person one would thus administer less than 50 per cent of the Lethal Dose 50. It is unlikely that the Lethal Dose 50 for a man would be greater than that for mice and therefore the conclusion seemed just that 1 gramme of "Merthiolate" was not toxic. Further evidence of this non-toxic nature was the fact that large amounts of serum containing "Merthiolate" were administered to many patients without any toxic or untoward reactions.

Later the question of whether or not "Merthiolate" can accumulate in the body and act as a slow poison was raised. Again, there was no evidence from clinical experience to indicate that toxic effects may be delayed. On the other hand, little was known of the mode of excretion of "Merthiolate" because of the extreme difficulty in estimating the infinitesimal quantities that would appear in urine or faeces.

PRECIPITATION AND TURBIDITY OF SERUM

When freshly prepared, serum is crystal clear in appearance, but as it ages it becomes turbid and develops a precipitate. A considerable amount of investigation was undertaken on the nature of this turbidity and precipitation. The three main clinical varieties may be summarised as follows:

(1) FIBRINOGEN DENATURATION.
Early.
Flaking in appearance.
Small in amount.

(2) LIPO-GLOBULIN BREAKDOWN.
Occurs later.
Flocculent in appearance.
Major cause of turbidity.
Agitation accelerates.

(3) CALCIUM STEARATE FORMATION.
Result of rise in pH.
Transparent flakes, often floating.
Only occurs in old serum.

All these forms of precipitates:

(1) Are accelerated by high temperature, storage and agitation;

(2) Are non-toxic to the patient;

(3) Do not reduce the therapeutic value of the serum.

From the work done on precipitates in serum the following information has been gained. When the plasma is clotted a small amount of fibrinogen remains in the serum. This fibrinogen has been altered in such a way that it is no longer susceptible to the action of thrombin and gradually precipitates in fine flakes. It is relatively insignificant as a cause in the turbidity as it is small in amount.

The major form of precipitation is due to a breakdown of the lipo-globulin complex; lipoid occurs in serum in association with a certain amount of beta-globulin. The complex is broken and both components precipitate. The precipitate is uniformly distributed throughout the serum.

Calcium stearate can often be seen as fine transparent flakes which float on the surface of the serum and resemble fungi in appearance. It forms only in old serum and as a result of a rise of pH. Because albumin, the main osmotic component, is not affected, precipitation does not reduce the therapeutic value of the serum.

Liquid serum which has been stored at refrigeration temperature will not develop turbidity as rapidly as will serum stored at higher temperatures. For this reason refrigeration storage is desirable, but it must be realised that if serum is stored at higher temperatures as is sometimes necessary, there is no loss of therapeutic efficacy and toxicity will not develop.

OTHER WORK IN TRANSFUSION UNITS

During the war years the allotment of pooled serum to the armed forces and for civilian needs was controlled by the heads of medical services in consultation with the local Red Cross transfusion service committees. A rough estimate of 30 litres of serum a week per 100 expected casualties per week was used as basis for a land force. For civilian purposes and to provide for emergency requirements a considerable stock of pooled serum was held in each State.

One interesting aspect of the increasing use of serum for post-operative shock may also be mentioned. After the cessation of hostilites serum became so popular in civilian practice that demand exceeded supply, and an appeal was necessary from the Chairman of the Australian Red Cross Society Blood Transfusion Service to surgeons to use more blood and less serum particularly for obstetric haemorrhage, as stocks of serum were threatened with exhaustion.

Blood destined to be used as serum could of course be of any group, but it was pointed out by Rachel Jakobowicz and Lucy Bryce that it was advantageous to include in pooled batches many individual samples of serum from AB, A, and B groups and to limit the use of O serum, particularly if of high or unknown titre.

Many aspects of blood transfusion were investigated at the blood preparation units. Dr Lucy Bryce stated the following as ideal requirements for the selection of donors. It is better for a donor to be anonymous, and important that certain physical conditions be regarded as grounds for rejection. These include anaemia causing a haemoglobin level of less than 85 per cent; a reaction to the Wassermann or Kahn test; a history of an illness which may be adversely affected by the giving of blood, or which may be transmitted to the recipient; an attack of malaria within the preceding six months, except that this is no contraindication for the use of the donor's serum; allergic complaints; jaundice within the preceding six months; a history suggesting an active virus disease and pregnancy or childbirth within the preceding nine months. Donors who themselves have received transfusion are tested for anomalous antibodies, and any necessary action taken on the findings. Hypertensive subjects were not welcomed as donors as their vascular reactions following bleeding were occasionally pronounced if the blood pressure exceeded 200 millimetres. The haemoglobin level of donors was important. Lucy Bryce and Rachel Jakobowicz after examining 4,110 men and 8,956 women donors found no seasonal changes or significant alteration in haemoglobin levels due to age. Men showed no substantial change after giving blood, women showed some recession of haemoglobin value to a small degree, the percentage having less than 85 per cent haemoglobin rising from 4 to 9.75 after 5 or more bleedings. R. J. Walsh found that three monthly bleedings did not affect the haemoglobin levels in men or women to any important extent. It is of interest that Walsh and Sewell showed that the effects of removal of half a litre of blood from healthy males are most evident only after the fourth day.

The reasons for adopting only group O blood for despatch to the army were to reduce wastage and to obviate having to rely solely on the soldier's identification disc as a guide to compatibility. The good results from this practice have helped to remove at least some of the prejudice in some quarters against the employment of the universal donor.

The drying of serum was carried out in several centres with special equipment, and recent technical advances were incorporated in this work. The separation of plasma from blood corpuscles was conveniently done in a commercial separator, with the use of such speed as would secure a maximum yield without damaging the cells. Major J. F. Funder, of Adelaide, and Dr F. B. Byrom, of Sydney, carried out valuable developmental work on the drying of serum. By courtesy of the N.S.W. Permanent Post-Graduate Committee in Medicine, and helped by grants from the Royal Australian College of Surgeons, the National Health and Medical Research Council and the Australian Red Cross Society, Dr Byrom worked on this problem at the Prince Henry Hospital at the University of Sydney for most of the early years of the war. Late in 1944 the army medical services decided that dry serum would no longer be required, and drying was discontinued. Investigations were carried out on the precipitates in serum, already referred to, and these proved that the formation of a lipoglobulin complex could be prevented by treatment with ether. Anticoagulants were also examined, and though the solution recommended by the British Medical Research Council was adopted, later work showed that a modified citric acid-sodium citrate glucose solution could be made which caused no change in the size of the red cells, and which prolonged their survival time *in vivo*.

Considerable investigation was also carried out on the agglutinins present in some bloods: this work was of particular value in civilian applications of knowledge concerning the Rh factors. A limited amount of anti-Rh serum was prepared to test for the presence of these agglutinins in the blood of patients likely to need multiple transfusions in military hospitals. Another activity of Blood Preparation Units was the production of bone marrow extract for certain aplastic blood disorders, but sufficient experience was not gained to allow its value to be assessed.

TRANSFUSION REACTIONS

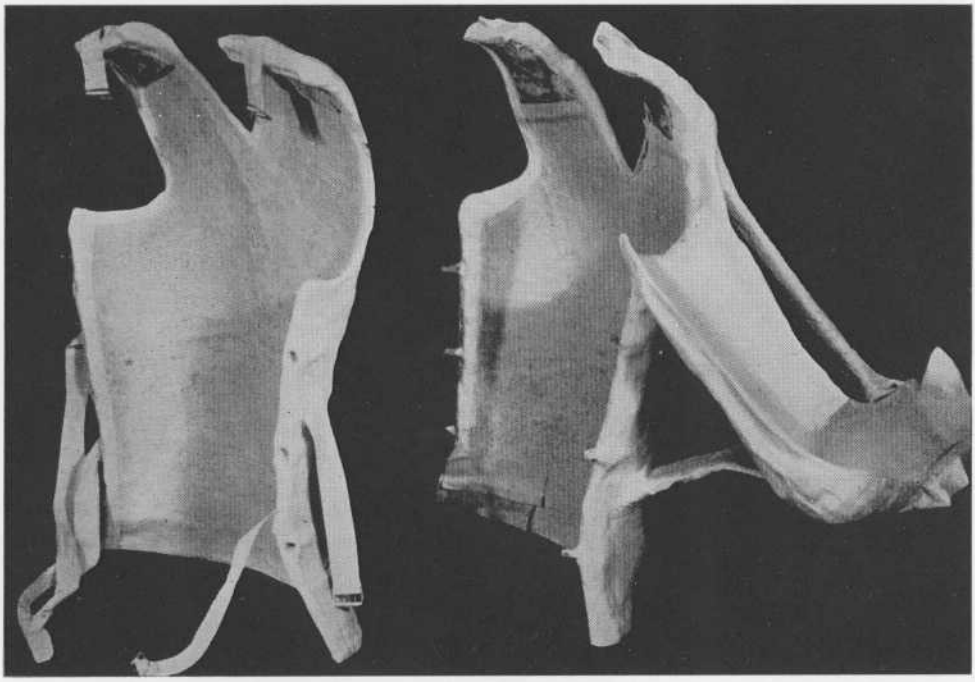
The occurrence of immediate reactions has been mentioned in connection with transfusions in the field. In general the most common causes were pyrogens introduced by a sub-optimal technique in cleaning or sterilisation, and an unduly rapid rate, particularly in debilitated persons. As pointed out previously, they have not been of serious significance. A special enquiry was initiated in Sydney and the results of transfusion of a total of 2,386 litres of blood were analysed by Major R. J. Walsh. Marjorie Bick also reported the experiences of the first four years of transfusion work in Victoria and found very few febrile reactions and only seven instances of jaundice. Walsh's series did not include transfusions of group O blood despatched to army units. He recorded only three



External bridge and rubber sling to correct medial bowing.



Cast applied with Roger Anderson pins *in situ*.



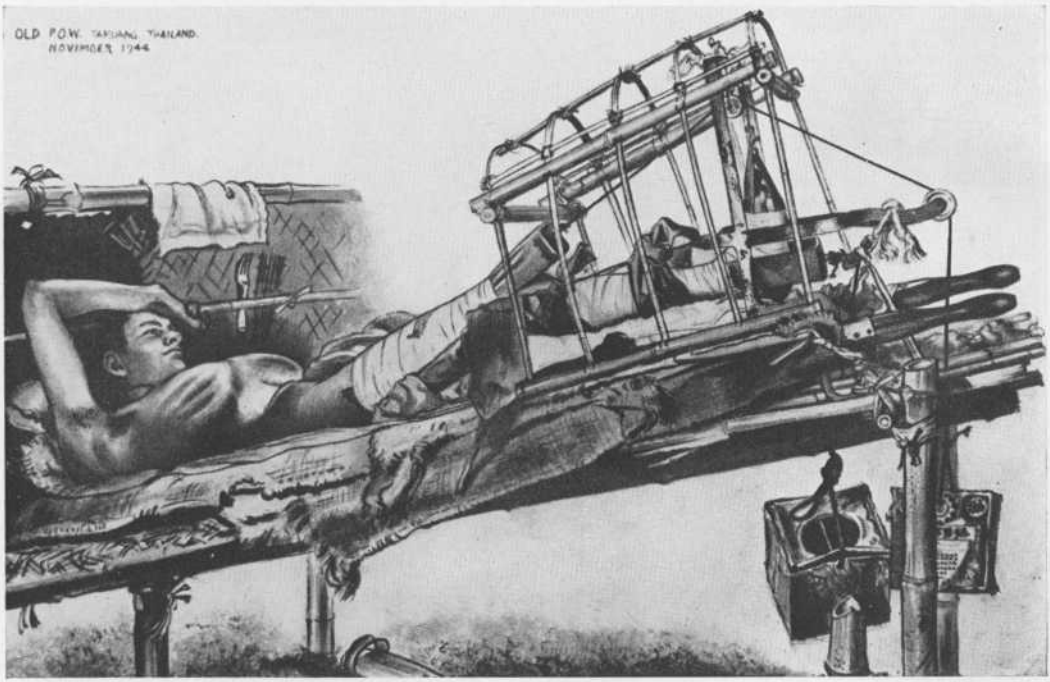
(G. Godfrey)

Two sections of the prefabricated cast.



(A. O. Watson)

Captain D. O. Leslie applying plaster at Myola.



(Drawn by A. G. Old)

Extension for fractured femur: Tamuang.

haemolytic reactions and perhaps one other doubtful, and two of anaphylactic nature due to sensitivity to allergens in the blood. Nineteen urticarial reactions were found, eleven of these occurring when sulphathiazole was added to the blood. They were rather severe in type, and the use of sulphathiazole in this connection was therefore discontinued. The risks of repeated transfusions and of circulatory reactions were pointed out, particularly when rapid transfusion was given to unsuitable patients. In all a great number of transfusions was carried out with negligible trouble.

HOMOLOGOUS SERUM JAUNDICE

Jaundice due to a mild degree of haemolysis in transfused blood was sometimes seen, as has been recorded. In 1942 in the Middle East the frequency of jaundice soon after transfusion was at times noteworthy, but of course this type of jaundice has no relation whatever to the variety of infective hepatitis which has been so often transmitted in pooled serum. Numbers of these latter infections were seen in Australia, but nearly all occurred in Allied servicemen and women who had received inoculations of certain batches of yellow fever vaccine carrying the virus. No large scale enquiry was made concerning homologous serum jaundice in the Australian forces, but the incidence of infective hepatitis was known and was watched carefully. Very little of this infection arose on the Australian mainland during the war period. It was not uncommon in the Middle East during certain seasons and in certain areas, as has been shown in the section dealing with the subject. It was also endemic in New Guinea, especially during the campaigns of 1942-1943 and from the later part of 1943 to early 1944. In the latter period the incidence was about 10 per thousand per year. It seems certain that the homologous serum jaundice with its usually severe symptoms and long incubation period would have been noted in the services had it occurred to any perceptible degree in men who had received pooled serum after wounds, injuries or burns. An enquiry was made into the incidence of jaundice in the Australian Military Forces on the basis of examining nominal rolls of all those receiving transfusion in operational areas. Among 341 men so traced no instance of jaundice was discovered. *A priori* it would be expected that in pooled serum derived from blood taken from civilians in Australia during the war years the attenuation of the virus of hepatitis, if introduced at all, would be of a high order. For these reasons it can be stated that homologous serum jaundice was not a significant problem in the use of pooled serum in Australia. Nevertheless keen interest in the subject has been maintained by the Red Cross Transfusion Service, and investigations are being continued.

RETROSPECT

The great advances made in the application of resuscitation were clearly seen as the war progressed, and as the material and methods for this literally vital work were not only freely available but were also in the hands of specially trained teams, this allowed surgeons to concentrate on their problems in forward operating centres. Further, insistence on the im-

portance of maintaining in the sick and wounded an efficient volume of physiologically adequate blood ensured greater speed and certainty in convalescence. The amount of blood and serum used up to the end of October 1945 is shown in the appendix: it emphasises the importance of an organisation which made possible a direct and continuous link between the well and the sick which is unique in the practice of medicine.

APPENDIX

Red Cross Blood Transfusion Service

Summary of Reports sent from State Services to National HQ at end of October 1945

Total No. of donors on the rolls in Australia		96,620
Serum.		
Total distribution since inception of Service:		
Liquid Serum—for civilian use	11,714	litres
defence use	35,486	„
Dried Serum—for civilian use	589	„
defence use	7,183	„
	54,972	„
In reserve—Liquid	2,932	„
Dried	1,244	„
Total processed	59,148	„
Stored Blood.		
Total distribution during war period:		
For civilian use	22,137	„
defence use	13,585	„
	35,722	„

Since approx. 3 donors are used to obtain 1 litre of serum and
„ 2 „ „ „ „ „ 1 „ „ stored blood.
Therefore 177,444 donors have been called for serum, and
71,444 „ „ „ „ „ stored blood.

Total 248,888 donors used for these purposes during the war.

The total number of calls made throughout Australia for all purposes (including individual transfusions) since inception of the Service is recorded as 314,472.

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CHAPTER 35

BURNS

DURING the earlier phases of the war the restricted combat opportunities of the Australian armed forces caused them to base their policy for the treatment of burns more on lessons learnt elsewhere than on personal experiences. Fortunately for them there were no casualties among civilians from air attacks, and during the first year of war most of the cases of burns treated on land at least were due to accidents, often but not always associated with mishaps among men in training. This did not make it easier to lay down policy, for the atmosphere in 1939-1940 was one of controversy.

Coagulation with tanning agents, tannic acid in particular since its introduction in 1925, had been hailed as a great advance as a life saving method. Its undoubted value had, however, aroused enthusiasm which was not always justified, and specialised experiences such as those in Britain soon showed its drawbacks. Controversy was focussed on the best methods of first aid. It was evident that the supporters of the "tan" and "no-tan" schools were not always speaking of the same things, and that the outlook of the medical officer who saw his patient almost from the moment when he was burnt, was different from that of the surgeon in a base hospital, faced with problems of infection, scarring and repair. Much was arguable, also. Coagulating agents used were tannic acid, silver nitrate, or a combination of both, and combinations of dyes like triple dye (1 per cent gentian violet in aqueous solution, with added 1/2,000 brilliant green and 1/1,000 acriflavine). The protective coating they gave varied in toughness, pliability and thickness with the agent used, and thus varied also in its tendency to crack, especially on mobile skin surfaces. Cracking in turn favoured infection. Encircling coagulum on limbs, and in particular on hands and fingers, acted like a tight splint, and restricted tissue circulation and nutrition, an effect enhanced by oedema. It was also important to remember that these parts were often burnt more severely than others, especially in some types of war injury, for example those due to fire in aircraft.

It was not long before the general rule was adopted not to use coagulation on faces, hands, feet, fingers or genitals. The advocates of coagulation as a first aid measure, however, pointed out that bad results such as fixation of interphalangeal joints and functionless spindle-shaped fingers were due not only to excessive zeal in tanning but to the intense though brief effect of very high temperatures. Special types of injuries were inflicted by bomb explosions and by cockpit fires in aircraft. In the latter particularly the face and backs of the hands were often badly burnt and the damage caused by brief exposure to a blast of flame could not be undone. However, the degree of damage could not be assessed when first aid was given, and the restriction of tanning was right and inevitable.

In 1940 controversy was active: probably there was some exaggeration on both sides, and as Colonel W. A. Hailes pointed out in technical instructions, the protagonists are apt to forget the conditions prevailing at the time of injury and the facilities available. The forces in the Middle East at this time were kept informed by Sir T. P. Dunhill, who had originally been appointed as Consulting Surgeon to the Australian Army in London, and who sent regular accounts of all matters of military surgical importance. The value of saline baths and *tulle gras* or "Vaseline" gauze was familiar to surgeons with the A.I.F., though they recognised that these methods were fully applicable only in fixed well-equipped units. The A.I.F. instructions made clear the claims made for the two different methods of handling burns.

About this time too there was a combined discussion on burns at a meeting of the Section of Surgery of the Royal Society of Medicine in London. This summarised well the position as it was at the end of 1940. Naval experience had soon disproved the view that tannic acid was a completely satisfactory application to burnt areas. War burns usually combined damage of first, second and third degree, the latter denoting complete loss of skin in which the affected area was dull and without evidence of circulation. The air force experience had enabled intensive study to be made of severe burns of special and often localised nature. Both these Services had reason to stress the importance of protective covering of the skin in prevention of severe burning, first realised in the Battle of Jutland in 1916. The disastrous results sometimes seen in burns of the face and the hands emphasised the need for more than short range considerations of first aid: as Wing Commander C. Flemming aptly said: "We must think of the patient not only in terms of life, but of living".

Professor A. H. McIndoe pointed out that three ends were to be served, the saving of life, the efficient treatment of the burnt areas and the preservation of function. The last requirement was most intimately concerned with the degree of skin loss sustained, and therefore of third degree burns. Those who carried out the hospital treatment of burnt men found that tanning was not advisable on burns of the third degree, as sloughs, due to infection, formed which delayed healing. A specialised method of interest was described during this discussion, that of the envelopes introduced by Surgeon Lieut-Commander John Bunyan, R.N.V.R. These were bags which could be sealed to various parts of the body, particularly the limbs, through which intermittent irrigation could be carried out with water, saline or hypochlorite solution.

The general systemic disturbances were discussed also. The mechanism and nature of some of these were obscure, and in fact still are to some extent, but those considerations affecting treatment were reasonably clear. Primary shock was less important than secondary shock, but it was agreed that adequate dosage with morphine was essential. Experience not only with burns but with other painful conditions has shown during this war that there is still a tendency for medical men to be unduly timid about giving a really efficient dose of morphine, such as 1/3 or 1/2 grain. Some

burns cause much more pain than others. Surgeon-Lieutenant A. Rowlands drew attention to the intense suffering caused by burns involving the head and neck and conjunctivae, such as were seen after an air raid on Malta in 1941. Secondary shock was common and was known to be connected with fluid loss. The early success of coagulation with tannic acid had emphasised unduly the importance of external losses of protein-rich body fluid from raw surfaces, but it was now recognised that local oedema accounted for large losses of fluid from the active circulation. Nevertheless the actual amount of protein lost to the body by surface exudate can be considerable, as was found in other types of war wounds. Haemo-concentration could be to a good extent countered by the giving of serum or plasma, ideally combined with adrenal cortical hormone, though the latter would not be freely available in military practice. The exact significance of that conveniently hellenised word "toxaemia" was not known. Whether it was solely the outcome of infection or due to tissue metabolites or products of destroyed tissue was not clear, but the plain indication was to prevent and limit infection by rigid precautions, and by the use of such agents as sulphanilamide.

The A.I.F. technical instructions referred to this discussion, and after pointing out the controversial subjects, largely followed instructions adopted for the R.A.F. Coagulation was prohibited on the fingers and on the face. The importance of retention of function of the eyelids was stressed, as they were frequently involved, though the rapidity of the eye-closure reflex usually saved the eyes. Therefore for the face and fingers the *tulle gras* method alone was recommended. The definition of a minor burn adopted was that it was a first or second degree burn affecting only 1 per cent of the total body surface, that is 28 square inches. Amongst major burns were included all burns of the hands, face, flexures or genitals.

In forward areas tannic or gentian violet was used for all parts of the body surface except these, where sterile "Vaseline" was used instead. Tannic jelly had not been found completely satisfactory at this time, as uniform tanning could not always be obtained. Saline and acriflavine were then undergoing comparative tests as first dressings at selected aid posts. One drawback to the use of dyes as mild coagulants was that their supply was then limited in the Middle East. The recommended treatment for shock was absolute rest, with raising of the foot of the bed, sufficient warmth, free administration of morphine, hot fluids by mouth or rectum, oxygen and intravenous serum or plasma. The wisdom of care in the application of warmth to shocked patients was then becoming apparent. The table drawn up by Black was included in the A.I.F. technical instruction for the guidance of medical officers in determining the dosage of serum or plasma by the percentage of haemoglobin in the blood (appendix). Due emphasis was laid on the differences necessary in treating burns of varying degree and extent affecting different areas of the body and under different conditions. Special instructions were given for the handling of phosphorus burns as from incendiary bombs or self-igniting phosphorus

grenades; these directed the avoidance of all oily dressings, and the local use of immersion in water, or wet pads, particles of phosphorus being also removed under water.

The above general principles were carried out during the first campaign in North Africa by the A.I.F. medical services. Here problems of evacuation arose, for after initial treatment of burnt soldiers in the desert some time inevitably elapsed before further treatment could be pursued in a casualty clearing station or a hospital. During the siege of Tobruk, where the 2/4th Australian General Hospital really carried out the functions of a clearing station, it was found that the treatment of burns there depended somewhat on the prevailing conditions governing evacuation. Tanning was used on the trunk and limbs, except for the flexures. Triple dye was tried on the face and hands but without much success, as the soft coagulum came off easily. *Tulle gras* was found to be an improvement, and greasy dressings in general proved useful. In August 1941 patients were not arriving in good condition at the base because they were moved on just at the time when skilled attention was most required. A special burns centre was then established at the 2/4th A.G.H. in Tobruk, with facilities for saline packs and baths, but this was not used while evacuation to Alexandria was prompt and free. About this time, too, pooled serum was available from Australia, and gave excellent results without reactions. The presence of the 2/11th A.G.H. at Alexandria was found very beneficial to these patients.

At this hospital experience accumulated in the handling of men burnt in air raids during the evacuation from Greece and Crete. Most of these men were treated with picric gauze on the ships and suffered from the effects of flash on the exposed parts. The affected areas were chiefly on face and neck, 85 per cent, and hands and arms, 58 per cent. They were treated by cleaning, spraying with tannic acid, the application of tannic jelly, or, on parts for which these dressings were not suitable, with *tulle gras*. The importance of adequate but gentle cleaning of the affected areas under anaesthesia was recognised in all fixed units receiving patients at a stage sufficiently early for this to be done.

At the larger base hospitals opportunities for more deliberate treatment confirmed the value of saline baths and packs. At the 2/2nd A.G.H. at Kantara, where a surgical plastic unit was established, baths were introduced with extemporised equipment, and skin grafting was done as early as possible. At the other hospitals in Palestine too the better cosmetic and functional results of such methods were firmly established by 1941. It was found that small deep burns such as those on the dorsum of the foot did not do well with tanning, but healed more quickly with sulphonamide powder and "Vaseline" gauze as a first dressing. The routine of dusting with a sulphonamide powder was generally adopted, though it was fully understood that this was an accessory aid in the prevention of infection, and that other rigid precautions were imperative. Local application of sulphonamide on a wide area could only be made guardedly, on account of the degree of absorption possible. Completely separate wards for septic

wounds were no doubt a help in limiting the risk of infection in surgical wards. After the campaign in Syria when the 2/1st and 2/3rd Casualty Clearing Stations carried out work usually done by general hospitals the experience was the same, and the judicious use of tanning and sulphanilamide with "Vaseline" gauze and baths according to requirements were found most satisfactory, provided preliminary cleansing was done.

In June 1942 a meeting of the Royal Australasian College of Surgeons was held in Australia at which a symposium was presented on "Burns". The opinions voiced there reflected the general moderate and balanced opinion which recognised that no set treatment for burns could be dogmatically laid down, owing to the differing environments in which first treatment was carried out. A use for coagulation was still recognised, and the agent was still some variant of tannic acid, such as 5-10 per cent tannic acid or 10 per cent silver nitrate or a combination of both. The three dye tan was found to be too soft and easily removed. Colonel Hailes in a review published at this time remarked that there were infinite variations between the excellent results of baths and *tulle gras* and the equally good results of tanning second degree burns. Third degree burns were best treated with baths, but if a long journey faced the patient tanning was perhaps advisable to control loss of fluid.

Major B. K. Rank, who had organised the first A.I.F. facio-maxillary or plastic unit, at the 2/2nd A.G.H. at Kantara, stressed the importance of the two aims of early treatment, the saving of life if this was threatened, and the carrying out of such local measures as would prepare the field for "the only adequate application for any severe burn—live skin". The dangers of infection were well publicised at this time too, though no additional weapons were then available to combat it. Efficient cleansing as previously mentioned was recognised to be essential as a preventive of infection and aid to healing, but excessive zeal was positively harmful. Satisfactory trials were made of "Cetavlon" (C.T.A.B.), a wetting agent with a molecular "tail" which gave it hydrophilic properties. This was suitable only for initial use, owing to the possibility of its setting up a dermatitis.

The question of the absorption of sulphanilamide from the treated areas roused some interest at this time. J. de Vidas and A. C. McEachern, from R.A.A.F. experience, found that 7.5 per cent sulphanilamide in tannic acid did not lessen its coagulant effect and caused a rise to 5.0 milligrammes per cent in the blood in eight to nine hours. The same proportion of sulphanilamide incorporated in a greasy dressing caused no such rise. Pressure was often used as an adjunct to other methods of limiting loss of body fluid: this was valuable, though even applied through bandages it needed great care, and still more when an occluding plaster was used. The preventive value of clothing has already been mentioned, and here the experience in the air force underlined in a specialised way that of the navy.

The experience of the Royal Australian Navy may be conveniently recounted here. In this service the injured man usually had to be held for some time in the same environment where his first aid dressings were

applied. Methods used had to be suitable for all types of ship, down to the small motor launches, and easily applied by relatively unskilled persons. Surgeon-Commander L. Lockwood in a brief review of the evolution of treatment of burns pointed out how the lesson of protective clothing was slowly learnt. More damage and loss of life occurred during the attacks on convoys returning from Greece and Crete in 1941 than was inevitable, owing to the lack of such precautions. The need for rapid and simple methods of local treatment was apparent in such emergencies as the bombing of the 27,000 ton *Georgic* at Suez in July 1941, and during the actions between Singapore and Java early in 1942. In the latter it was observed that uncomplicated burning of even over a third of the body surface was compatible with recovery, but men with additional wounds or blast injuries succumbed. As a simple method numbers of medical officers in ships favoured triple dye, or a dye jelly: others preferred a greasy dressing from the start. Surgeon-Commander J. M. Flattery preferred the latter and in the damaging actions in which H.M.A.S. *Australia* was involved in the Pacific found that in a heavy cruiser a minimum of 50 pounds of sterile "Vaseline" gauze should be kept in readiness, distributed between the action stations. The choice of this method was influenced by discussions with medical officers of units of the American Navy on experiences at Pearl Harbour.

It is interesting here to look back to the 1914-1918 war, and to recall the "Ambrine" outfits which provided a simply applied clean wax to the burnt surface. The pendulum after swinging away to tanning agents has now swung back part of the way.

During the later years of the war the principal changes in the surgical technique of handling burns were due to the introduction of more potent agents to combat sepsis, in particular penicillin. The local and general applications of this antibiotic permitted the safe use of simple pressure dressings, shortened the period of healing and therefore hastened the day when skin could be grafted on deeply burned areas. This rightly threw more emphasis on the ideal of looking more to the end, while yielded nothing in carrying out life-saving measures.

Prevention came to mean more also. In the Royal Australian Navy some careful observations were made in relation to the use of antiflash gear. Surgeon-Lieutenant Graeme L. Grove, R.A.N.R., based a report on this subject on investigations made on H.M.A.S. *Australia*. Briefly it was established that antiflash gear efficiently protected the parts covered. The degree of protection was greater if the material of this gear was still effectively proofed: where the proofing had been in part removed by washing some degree of protection was still given, but this was considerably reduced. Other clothing materials afforded some protection, particularly from brief exposure to bomb flash, but this was only slight where the cloth was thin or porous and where the heat encountered was great and at close quarters, as in petrol burns. Apparently no instructions or facilities had been given for reproofing antiflash gear after washing. It would seem that there is room for more research in this direction.

In other respects the experiences of the later war years in the Pacific and elsewhere confirmed the views generally accepted in 1943. Creams came more into use, chiefly as excipients of bacteriostatic substances, and with further refinement of their constitution, these were a distinct advance. At first they were chiefly used in base areas, but were more widely available later. Trial was made of the Bunyan bags in the Middle East forces, and this application of intermittent irrigation was found of value. However, considerations of simplicity and ease of application and maintenance naturally restricted this and other more refined methods in a war which diffused forces and medical units over wide areas, often difficult of access.

During the later years of war, when facilities were available for determining the concentration of protein in the plasma at the bedside, fluid replacement after burns was more exactly controlled. Though the results of this test and of haemoglobin estimations were at times misleading, they were of distinct help. Latterly the importance of loss of sodium has been recognised, and thus the value of transfusion of whole blood and electrolytes. After the first few days a high protein diet has been generally adopted.

Although the question of "toxaemia" and its causes and results was but little investigated, a few observations on various toxic manifestations in burnt patients were made. Bilateral retinitis was reported by Newson and Armstrong following burns, in which "cotton-wool" patches were seen in the perimacular regions, which slowly cleared. Liver necrosis was investigated also in a small series by Jackson. Out of eight livers examined at autopsy on men dying from burns two showed extensive necrotic changes. These men had been treated with tannic acid and silver nitrate; in others treated by different methods only cloudy swelling of the liver cells was found.

The story of the treatment of burns from 1939-1945 is like that of many other medical and surgical subjects. Strong advocacy of new technical advances is valuable, for no weak voice can arouse general attention, but it is always necessary to try to see where we are going, and to base our views on the established principles of the foundation medical sciences.

APPENDIX

Plasma loss from burns, assuming as standards

Haemoglobin 100%
Blood Volume 5 litres
Plasma Volume 3 litres.

Hb.	Blood Volume	Plasma Volume	Plasma Deficit
105	4.75	2.75	250
110	4.55	2.55	450
120	4.15	2.15	850
125	4.0	2.0	1,000
135	3.7	1.7	1,300
145	3.4	1.45	1,550
150	3.35	1.35	1,650

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CHAPTER 36

WOUNDS OF THE UPPER EXTREMITY

THE technical instructions issued in the Middle East stated that experience in forward areas had shown that if a wound of the upper limb involving a bone was excised, a "Vaseline" gauze dressing applied and the limb maintained in the correct position, the results were usually satisfactory. It would be more correct to say that the results were satisfactory only if the recommended procedures were carried out fully and correctly. Adequate excision should include adequate incision of the deep fascia, an important matter in the upper extremity as the otherwise resultant oedema may have serious effects on the lower arm and hand. The greatest difficulty lay in the adequate immobilisation of the limb during transit, especially when the humerus was fractured. It was difficult to apply a plaster spica to an anaesthetised patient; therefore the method advised for early control of such injuries was to fix the limb to the thoracic wall. It was of course necessary to support the forearm and hand in plaster. Even so, patients sent over a long rough road occasionally arrived with wrist drop. Plaster slabs controlling the shoulder and the extremity were not always proof against breaking, especially if the plaster was not of good quality or not applied with sufficient art and care. For sending patients with bony injuries of the upper arm from Tobruk to Alexandria a two-towel binding or clove hitch was used to hold the arm to the side, with a covering plaster shell.

Such faults as the occurrence of pressure lesions and the breaking of casts were early made evident in the desert campaigns, owing to the hard travelling to which many patients were perforce subjected. They were due in part to a certain lack of specialised experience in plaster technique and in part to the quality of the plaster obtainable. It should be pointed out that the technique of applying plaster, especially in difficult and unusual circumstances, is less easily attained when the surgeon in forward areas has not the advantage of seeing the results of his work. With wounds of soft tissues of the arm uncomplicated by bony injuries, immobilisation for transit was satisfactorily obtained by the use of the collar and cuff method, with the arm bound to the side and reinforced with a few turns of plaster bandage.

Immobilisation was of course much more difficult when the humerus was fractured. The site of the fracture also made a difference, as some degree of abduction, up to 30 or 40 degrees, was necessary when the fracture involved the upper third of the humerus. The abducted position was not an easy one for travelling. As a rule an upper arm could satisfactorily be put up only in an abducted position in a forward base unit like a casualty clearing station. During the later stages of the siege of Tobruk patients were successfully sent to Alexandria on naval ships with a shoulder spica maintaining the arm at an angle of 40 degrees. Care was always taken to apply the spica with the humerus in front of the coronal

plane of the body. As the necessary manoeuvres could not be performed on an anaesthetised patient considerable discomfort was caused to the patient by the application of a full shoulder spica. This could be minimised by the deft and rapid handling of a good team, and by some degree of analgesia, best secured by the intravenous administration of morphine. To give adequate immobilisation during transit a spica had to be moulded over the iliac crest, extending to the axilla and moulded over the shoulder. Good fixation with some abduction could then be ensured by reinforcement with a plaster bridge from the arm just above the elbow. As a rule plasters of the upper extremity had to be removed in seven to ten days.

In spite of all endeavours to secure immobilisation and control of a fractured humerus, patients with this injury in 1942 were still suffering discomfort in transit. During the battle of El Alamein the staff of the 2/7th Australian General Hospital saw numbers of patients arrive after an uncomfortable journey with inadequate fixation of the limb. The official recommendation of the British Middle East Force medical services was a "U" plaster, but Australian experience did not find this serviceable or comfortable for all fractures of the humerus. If correctly moulded it was satisfactory for fractures of the lower half of the humerus, and formed a good framework for building a light cast which could be fastened to the side. Slabs still occasionally broke in transit and could not be trusted. This depended somewhat on the plaster. "Cellona" bandages were quick-setting and strong; some of the loose plaster sent to the Middle East was, however, of poor quality, slow setting and lacking in strength. Some plaster was obtained from captured German material; this was slow in setting but reliable. Plaster from Italian sources was not useful.

When the war began in the Pacific Islands there was still room for improvement, and different ideas and methods were put to trial. A surgical team at Soputa found that one binder with an axillary and forearm slab gave comfortable travel, but here air evacuation was playing an important part, and the journey by this route was short. It was still found hard to ensure comfort to a man who had to travel a slow, rough, difficult road to the base. Even in 1944 in New Guinea men with fracture of the humerus arrived after such journeys showing the effects of pain and shock. The "hanging cast" was not found satisfactory: it controlled only the lower half of the arm, and sufficient support was not always given to the limb. Better fixation was given by a long plaster stretching from the iliac crest to the padded axilla, and running down the inner part of the arm. Another slab fitted to the posterior and outer aspects of the arm gave support there, and casings on the mid-upper arm and lower arm with a window gave good immobilisation. A bridge of plaster from the shoulder to the fore-arm, reinforced by Cramer wire, was a valuable device.

The tendency was in the later stages of the war to apply mechanically sound plasters which, without being too massive, could be relied upon to keep the limb truly immobilised. This emphasised the difficulty of applying an adequate case to an unconscious and supine man. It was necessary to carry out excisions and other necessary manoeuvres first, and as a second

stage procedure an adequate plaster was applied to control the whole upper limb with the patient conscious and sitting up, after adequate dosage with morphine, with or without scopolamine. Whatever the exact details of the procedure, plaster was then applied from the neck to the elbow, with support across to the opposite axilla, with a reinforcing slab. It was found important not to abduct the arm too far, as this caused epicondylar pressure, and bowing of the humerus.

Wounds of the lower part of the arm were less difficult to control in forward areas; excision with immediate application of plaster usually gave satisfactory results. The original Middle East instruction emphasised the importance of exercising great care lest the movements of metacarpo-phalangeal joints be limited. The detailed directions were as follows:

"Except in special circumstances care should be exercised to see that the volar slab of the plaster does not extend distally beyond the proximal transverse palmar crease. The volar plaster can be made longer and rolled back to this level thus adequately supporting the head of the metacarpal bones. The dorsal slab extends as far as distally as the head of the metacarpal bones. Unless there is a contra-indication, such as injury to the radial nerve, *the thumb should be in the position of function, in line with the shaft of the Radius,* i.e. in line with the flexion movement of the index finger."

The soundness of these and other directions given in the earlier years of the war was apparent during the island campaigns. Difficulties arose from faults in the application of correct principles not from the principles themselves. Perhaps even more stress could have been laid on the necessity for watching the hand for undue swelling and cyanosis and for recognising the importance of investigating the cause of pain in the limb. Splitting the plaster was then necessary; the need to take such action was more apparent in injuries of the forearm than those of the upper arm, but any tight plaster could easily give rise to serious trouble later. Another important detail was provision of enough dorsiflexion at the wrist to allow adequate movements of the fingers and thumb. Pressure sores were not infrequently seen on the ulnar side of the fifth metacarpal bone and over the head of the ulna, due to an ill-fitting cast.

Dental surgeons rendered useful service in collaborating with the treatment of fractures of the upper extremity. They contrived many useful appliances to secure immobilisation and traction; and made moulds for plastic procedures involving skin grafting.

Wounds of the hands were of paramount importance. The utmost permissible care was exercised to preserve all possible tissue, particularly the skin. The heads of the metacarpal bones were never removed unless damaged beyond chance of repair. It is significant that 10 per cent of the patients admitted to the A.I.F. Facio-maxillary and Plastic Surgery Unit in the Middle East required plastic treatment for wounds of the hand. In the later war years also reparative work on the hands formed a considerable bulk of the work done in plastic units. In the 2nd Facio-maxillary and Plastic Surgery Unit alone in the four and a half years preceding the end of the war 281 men required treatment for injuries of the hands; over

half of these were severe, and nearly a quarter of them were due to burns.

The problems of the wounded hand are so important that they are dealt with in the following separate section.

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CHAPTER 37

INJURIES OF THE HAND

THE development of the human hand is in itself an indication of the powers of the human brain, to whose physiological evolution it has greatly contributed. Therefore the tissues of the hand cannot adequately be replaced by the grafting of tissues from other parts of the body, which may compensate some loss in substance but cannot reproduce the hand's unique motor and sensory functions. Primary care of the residual elements of a wounded hand is thus of paramount importance, especially in the injuries of war, with its elements of high speed projectiles and destructive detonation. The scope of the reconstructive surgeon is determined by the adequacy of this primary treatment, and by the continuation of care during the wounded man's journey to a base hospital, so as to maintain correct posture and preserve movement, particularly of the digital joints. The importance of avoiding limitation of function in wounds of the hand was early indicated in the A.I.F. Middle East Technical Instruction No. 21 covering wounds of the upper extremity. In later instructions issued from army headquarters these warnings were amplified in Technical Instruction No. 17. This laid down that only devitalised tissue should be removed by *débridement* or excision, which should be as conservative as possible. Where amputation of the thumb or a digit could not be avoided it was to be minimal in amount, preserving at least the base of the first phalanx whenever possible, so as to prevent adduction of the remaining fingers. The final reparative and reconstructive procedures on damaged hands, being technical in nature, could be carried out only in a base hospital. In order to present the outlines of this work it is necessary first to recount the physiological and anatomical principles on which it rests, and then to indicate the troubles and complications due to departure from these principles.

THE FUNCTIONAL ANATOMY OF THE HAND

It is important to bear in mind the functions of the two arches in the hand, the proximal or carpal and the distal or metacarpal. The employment of the thenar and hypothenar muscle groups elevates the radial and ulnar metacarpals and increases the depth of these arches. Thus the capacity of the palm is increased for grasping spherical objects, the strength of the palmar grip is correspondingly greater, and the convergence of the digits on the base of the thumb when flexed is ensured. This movement of the lateral borders of the hand is associated with the integrity of the median and ulnar nerves, with the opposition movement of the thumb and with the remarkable accommodation of the position of the finger tips to palm capacity. In the latter regard the finger tips are in line in the position of mid-flexion of the fingers but are out of line in full extension and full flexion.

Thus the hand and finger movements are complex combinations of antero-posterior motion of the fingers, the axes of which are constantly being altered by the arching and flattening of the palm and the opposition of the thumb.

Further, the interdigitation of the flexors and extensors at the base of the hand, as their tendons arise respectively from a common muscle belly, has an important application, for if any finger is held in full extension or full flexion, the adjoining fingers cannot be actively moved through a satisfactory range.

The degree of movement varies with different individuals and only an approximate estimate is possible. Thus the flexion of the proximal joint varies between 90°-110°, the middle 110°-130° and the distal joint 45°-90°. To effect this movement the shortening of the long flexors varies at different levels thus: wrist 1¼″, fingers 2¾″ and thumb 2¼″, while the long extensors shorten about 2″ in extension. In proportion to its length, this range of movement is very considerable and gives the fingers great mobility. The conservation of this movement in any reparative procedure has therefore an important influence upon the end result.

These anatomical considerations make clear the optimum position of function and the purpose of reconstructive measures.

The hand at rest assumes a midposition of the range of motion of all joints including the wrist. This brings the forearm halfway between pronation and supination, the wrist to 20° angle of dorsiflexion and 10° ulnar flexion, the thumb in partial opposition in a plane anterior to the palm with its joints partially flexed, and the fingers slightly flexed. The hand now fits round an elongated object of 1¾″ diameter lying across the palm at an angle of 45° and in the line of the transverse creases, and assumes the "holding the glass" position.

At all joints circumduction is possible except those of the fingers, which are thus limited to flexion and extension. This is important as the close adaptation of the finger joints and the presence of the collateral ligaments renders them particularly liable to stiffness with inactivity. The difference in length between the taut and the lax collateral finger ligaments is about 2 mm. This small degree of shortening may therefore result in a useless finger. The associated movement of the tendons in their gliding sheaths and in the carpal and finger tunnels emphasises the delicacy of the arrangement.

On these bases rest the principles of all operations on wounded hands whether primary or late.

ADEQUATE PRIMARY TREATMENT

It is essential to remove dead tissue, more particularly that which in time will form a deep sequestrum of bone or slough of tendon and favour suppuration. This necessitates a bloodless field—a desideratum best achieved with a sphygmomanometer cuff (at 200-250 mm. Hg.) surrounding the upper arm, the skin of which is protected by a towel. With this

combination no nerve or vessel injury is likely after periods of ischaemia up to two hours. Haemostasis is very important and a correct assessment of deep damage is essential for subsequent repair.

Fingers which will necessitate a prolonged course of treatment with a doubtful outcome are better removed at the primary operation in order that the rehabilitation of the residual hand may be commenced forthwith. Removal of skin must be practised with great conservation, so that if possible the bare area can be covered at the end of the operation. A finger which will be subsequently useless should be filleted so that its skin can be used for this purpose. If this can be achieved the after result may be greatly accelerated and improved. The thumb is so valuable a component of the mechanism of the hand that as much of it as possible should be saved. In gross injuries, primary nerve and tendon suture are not possible, and if in a gunshot wound these are associated with a compound fracture of the bony structure of the digit amputation is advisable. Haphazard amputations are of course to be deplored. Optimum sites should be aimed at even if not attainable in the primary operation. Though gas gangrene infection is almost unknown in the fingers undue risks should not be taken. Cautious but thorough *débridement* with systemic and local chemotherapy is important in the prophylaxis of sepsis.

RESULTS OF PRIMARY TREATMENT

The first treatment of wounded hands was not always as productive of good results in the Services as might be expected in civilian injuries. Combat injuries in themselves tended to produce more scarring, and this was sometimes extensive. By the time men with these wounds could be treated at a fully equipped plastic unit the finer manoeuvres such as tendon repair were perforce postponed until scars were replaced by soft tissue and joints were mobilised. It was only in the later stages of the war in the islands when the military situation was more under control, and when transport was more readily possible that this handicap could be overcome to any extent. Movement of these patients often not otherwise ill was gradual, and during a long journey they might be temporarily brought to rest in several medical units. Until the later periods most patients with wounded hands reached plastic units only after the lapse of two to four months. These delays did not encourage the patient to maintain movement of all the joints of the hand not immobilised for purposes of treatment. It is difficult to overestimate the damage done by neglect to move all available joints through the fullest possible range of movement many times a day. Some of the best examples of the value of maintaining movement were seen in the hands of those patients who had been instructed by the sister in charge of the ward at a forward hospital in New Guinea to move their fingers passively and actively through the full range three times daily. Equally important was the maintenance of the position of function of the damaged hand. Neglect in this respect results in a crippled and deformed hand for which rehabilitation is well-nigh impossible. The position of this type of hand is rather characteristic. The thumb is in the

"simian" position, being drawn into strong adduction against the index finger. This fixed position of the thumb is accompanied by obliteration of the metacarpal arch and the elimination and atrophy of the first interosseous space. The palm is narrowed by the wasting and fibrosis of the small muscles and the approximation of the metacarpal heads which results from shortening of the intermetacarpal transverse ligament. The contracture of the short muscles flexes the metacarpo-phalangeal joints and this position becomes fixed by the shortening of the collateral ligaments. The proximal interphalangeal joints are also hyperextended for the former reason, while the long flexor acts on the distal interphalangeal joint. The hand rapidly assumes this narrow flattened shape if attention is not paid from the very outset to its prevention, and no subsequent activity can compensate for neglect to splint the hand in the position of function at the primary operation. A few minutes' care at that juncture may save months of subsequent travail.

THE PROBLEM OF RECONSTRUCTION

In recent injuries, such as burns and recent wounds restoration could sometimes be accomplished rapidly, but with injuries of longer standing there were usually problems of fibrosis and contraction to solve. The following account is based on the experience of the plastic unit at 115th Military Hospital, Heidelberg, under Lieut-Colonel Rank. All patients reaching plastic units had received primary surgical treatment on the usual lines of wound management, except that a strictly conservative attitude to excisions and amputations was advocated and practised. Most of them had healing, or recently healed, soft tissue wounds or amputation stumps, and fractures which might or might not have united, but almost universally the small joints showed some degree of stiffness. Joint stiffness too readily arises from disuse associated with actual tendon or joint damage, from low grade reaction of inflammation, or from the immobilisation which is indicated in earlier phases of management. Spreading tissue infection or hand space infections were characteristically absent from the severe open hand injuries.

At this stage, the main efforts of treatment were to get all soft tissue wounds healed, and the small joints mobile. To the former end, eradication of surface infections was universally applied and palliative skin grafts were freely used wherever healing time could be saved. Retained foreign bodies, exposed tendon, bare bone or open joints were common factors retarding early healing and a late secondary *débridement* for such conditions was often well worth while. Where injury was fairly recent covering of bare bone or tendon with soft tissue flaps was done to preclude the adverse effects of exposure and a failing blood supply.

Re-establishment of joint function was the prime consideration, for if adequate mobility could not be restored to joints, future reparative procedures were often worthless or contraindicated unless directed to some cause of joint embarrassment. The importance of preventing joint stiffness is obvious. If previous immobilisation had been of short duration, active

efforts at function were usually sufficient to restore movement; but in a majority of the cases, this was too slow and often insufficient where multi-stage repairs were planned. On the other hand, forced passive manipulations prove unsatisfactory for small joints. Even if a good immediate passive effect was obtained, subsequent oedema and reaction prevented the object of movement, and fibrosis soon caused return of the *status quo ante*.

The principle of controlled and long continued light traction is the best aid to early restoration of finger joint mobility. Various types of traction splints were used to accomplish this. These were easily elaborated or modified to suit individual cases with the facilities available. Failure to obtain improvement emphasised again just how very important is the position of function of the hand, and how early treatment must respect this with reverence. For joints which were mal-fixed, apart from bone procedures such as wedge osteotomies and joint fixations to eliminate deformities, the only soft tissue procedure which proved of value was that of capsulotomy of the metacarpo-phalangeal joints for joints stiff in extension through long immobilisation in that position.

When all wounds have healed, and a short period of function or provocative massage has demonstrated no latent sepsis, when a worthwhile range of joint mobility is obtained, then, and only then, can the possibilities of plastic surgery of the hand be considered. This has a two-fold purpose —to restore to their normal function the parts of the hand which remain, and to reconstruct, or substitute for, parts which are lost.

Every case presents not only an objective surgical problem, but must be considered in relation to the subject. Improvements or results are relative only to an individual case. The more mutilated the hand, the more important any slight improvement is. For some of the more gross mutilations seen, efforts were justified to seek even meagre chances of improvement.

The efficiency of a hand remnant may be short of the optimum for many reasons. An exact anatomical diagnosis of the varying degrees of loss or distortion of skin, tendon, bone and/or nerve, is the essential basis of management. This is all obvious to close scrutiny, except in regard to tendons, where it is often impossible to tell the extent of tendon damage, or indeed if it exists at all, until a subsequent exploration is done. It is true that the notes of primary treatment are available, but the damage of primary injury is usually augmented by secondary damage of exposure, sepsis and fixation in scar tissue.

In the correction of the various deficiencies, the following methods were applied:—

1. *Scar disability which manifests uncomplicated skin loss*—Correct and timely management of scar disabilities reaches its acme of importance on the hand, where even a small scar can produce a large disability. Scar excision, re-establishment of the defect to its full extent, and making good the loss by grafting form the basis of correction. This may be satisfied by

many techniques. For uncomplicated skin loss, free grafts were generally applied—

(a) Whole skin grafts were commonly used for palmar regions, or areas about the fingers. With this method subsequent contraction of whole skin is negligible, its mobility and stability are good, and what is of special importance on the hand is that its return of sensation, though slow, eventually reaches closer to normality than that of thinner sections of skin.

(b) For large areas, especially on the dorsum of the hand, it is more general to apply a dermatome-cut graft approximately three-quarter skin thickness. This procedure has given most excellent results.

Scars which are painful or tender because of nerve involvement or adherence to bone are commonly demonstrated about the finger tips. For these cases, small direct flaps were applied with good result, though for individual fingers other than the thumb or index finger in an otherwise normal hand, partial amputations were often considered more economic.

2. *Scar disabilities, complicated by tendon damage*—Where exploration with a view to tendon repair is done, procedures must be planned with the knowledge that the affected soft tissue areas must be covered by a healthy flap of skin or fat.

(a) Local flaps, if available, make the procedure easy and non-cumbersome for the patient. Herein lies the great value of leaving redundant soft tissue or flaps from fingers amputated at primary operation. The filleted soft tissue of a useless finger may prove of inestimable value in future repair and alleviate the necessity for staged procedures.

(b) Direct flaps. If local flaps are not available, before tendon repair can be carried out the scar must be replaced by a direct flap, usually from the abdomen. This means a two or three-stage operation. Tendons are quite intolerant of even low grade infection, and repair is generally better left for a subsequent operation. Except in digital canals, direct tendon repairs are done where possible. Next in preference come transplants wherever possible from an homologous group of muscles having the same type function. In the grossly mutilated hand, tendons are often available which are otherwise rendered useless by the mutilation. Where deficiencies exist and subsequently transplants are not available, free tendon grafts are used.

The extensor tendon grafts do well, as indeed do most extensor tendon repairs. On the flexor aspect, good results have been obtained with grafts of flexor tendon deficiencies existing between the wrist and distal part of the palm, but where the graft was passed through the digital canal, good independent interphalangeal movement has been rarely obtained. In many of these cases, good strong flexion at the metacarpo-phalangeal joints has been obtained by the grafts, which, with some degree of fixed flexion deformity of interphalangeal joints, has salvaged what would otherwise often have been useless fingers. For reparative surgery of tendons, technique assumes vast importance. For best results, every finesse of atraumatic technique is required. Some special instruments, including tendon holders, Bunnel's stripper and tendon threader, are invaluable. They render radical exposure, groping and traumatising procedures unnecessary. The technical considerations, together with the common association of scar problem, render all these injuries best suited for treatment

in a plastic surgery unit. Australian surgeons agree with their American colleagues that early movement promotes undue fibrosis, and that more bad than good ensues by encouraging early function which depends on suture between ununited tendons. After tendon suture the parts were generally immobilised for three weeks with wrist and metacarpo-phalangeal joints half flexed. Active movements were then commenced on the inner range from the half flexed position. For the necessary after care physiotherapists proved invaluable.

3. *Compound scar disabilities associated with tendons and bone loss*— As a graft, bone is much more viable than tendon. In the relief of bone defects scar excision, bone graft and flap attachment can be done at the same operation. In this work, penicillin has permitted more liberty than was previously possible with safety. With bone deficiency corrected and a flap in *in situ,* tendon operations are best done later. After war injuries of the hand, deficiencies of the metacarpal bones have been frequent, and experience has shown that bone loss or loss of length in a metacarpal is an indication for bone graft. Many more metacarpals were grafted as experience accumulated. Too often stiff metacarpo-phalangeal joints result because shortening is accepted, or immobilisation is continued too long in the hope of a problematical union. With shortening of metacarpals, proximal subluxation of the metacarpo-phalangeal joint usually means a poorly functioning finger with stiff inter-phalangeal joints. Bone grafting of the metacarpals has been found a very easy and satisfactory procedure.

In considering restoration or substitution for parts lost, many mutilated hands have only left one or two fingers or finger stumps; some are even devoid of fingers. It is insufficient to accept many of these as end results, even though the remnant as such may have complete function.

Where the thumb is absent, or when there is nothing effective to which it can be opposed, the thumb stump may be added to or its length increased if there is some remnant of a metacarpal which can be moved by the thenar muscle. Something can also be supplied to which the thumb can be opposed if, for example, the other fingers are missing. Sometimes both elements of the "pinch" function were successfully restored to an otherwise useless member by reconstructing an animated pair of pincers.

With cognisance of these possibilities, in the primary treatment of severe mutilations of the hand, possible tissue salvage is not the only or chief consideration, but potential mobility. If a man has an intact thumb metacarpal, nothing should be done which will involve it by scarring, and he should be urged to practise and develop any movement which remains. Without explanation this might seem at the time useless and purposeless effort, but it may form the basis of a subsequent effective reconstruction.

The individual management of gross hand wounds is animated by the motive of evoking the optimum value from what is left, no matter how little. Any degree of hand usefulness or movement which can be effected is so much better than an amputation stump, and so much better than an artificial hand, that no thinking surgeon could or would but err on the side of conservatism in his primary treatment of hand mutilations.

The primary management of severe hand mutilations has a strong influence on subsequent reparative treatment. It warrants the services of the best surgeon available. Any excision must be conservative, and all possible soft tissue should be salvaged, even if there is no obvious immediate usefulness for it. Too much importance cannot be attached to the covering of all bare bone, joint or tendon with local soft tissue flaps, and primary grafts should be used even more freely either on the raw areas themselves or to make good the secondary defects left after the use of local flaps. Early immobilisation is just as important as for any recent wound, but it must respect the position of function and not be maintained a single day longer than necessary.

A final point of importance concerns intrinsic nerve injuries. The preservation or restoration of function of a damaged digital nerve may make a great difference to the usefulness of a wounded hand. Suture of a digital nerve should therefore be carried out when circumstances permit. If the separation of the severed ends cannot be overcome by simple suture a graft may succeed in bridging the anatomical and functional gap. The chief lesson learned in the care of wartime injuries of the hand has been that all treatment must be based on a sound knowledge of the structure and function of that beautifully complex member. Always the emphasis is on function.

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CHAPTER 38

WOUNDS OF THE LOWER EXTREMITY

COMPOUND fractures of the femur, particularly in its upper part, were the most serious injuries involving the extremities. The fracture of the bone was often but one wound of many, and associated wounds of the buttock, pelvis and abdominal contents were common, especially when the path of the missile was obliquely upwards. Buttock wounds were always potentially serious, as they were often extensive and involved abdominal viscera. Such wounds demanded high priority of treatment. A particularly serious injury was one affecting the upper femur and pelvis and the rectum. In the Middle East injuries of the lower extremities were by no means uncommon, owing to the frequency of land mines and other explosive devices concealed by the loose sand. Many of these involved the distal parts of the lower limbs, but the thigh injuries, usually due to gunshot or bomb wounds were more important because of the technical difficulties in handling them, the great degree of shock they cause, the risk of bone sepsis and the problems of transport of patients. In most of the early campaigns of the Middle East distances were great, and roads rough, and even in parts mere tracks; therefore, though methods of extension and fixation improved, most men with a fractured femur suffered considerable discomfort on the journey from the desert to Egypt. Where immobilisation was ineffective the patients arrived shocked. But even at its worst, the lot of men with fractured femurs was much better than in the early years of the 1914-1918 war. The Thomas splint did not have to fight for recognition, its value was established. The general opinion of surgeons was that a Thomas splint alone or with plaster was better than a plaster spica alone. As pointed out before, the Orr-Trueta methods could not be followed closely in this respect, owing to difficulties in maintaining alignment. The moving of a Thomas splint attached to a stretcher also caused trouble, as movement of the patient was easily reproduced at the site of the fracture.

During the siege of Tobruk, special attention was given to the problem of immobilisation of the fractured femur. Patients were transported by sea to Egypt at first by hospital ship and later on by naval ships, chiefly destroyers. Though the plaster methods of the Spanish war did not fit these conditions, plaster was found necessary in order to ensure that the injuries were undisturbed on arrival at the base. Thus, the plaster spica advocated by Trueta was the basis of the so-called Tobruk method, which was never an invariable routine, but was altered in detail as time went on. Thus appeared Tobruk plaster marks I, II and III, and in modified form it was used in the second Libyan campaign. While it is true that excision with the application of plaster was the standard method for these injuries in the early stages of the war in the Middle East, it was always recognised as having disadvantages as great as its advantages.

Littlejohn, who, as the officer directing the surgical division of the 2/4th Australian General Hospital in Tobruk was the chief protagonist of the method at this time, was fully aware of this, and has pointed out that its chief virtue was in facilitating transport from Tobruk to the base. It must be remembered, too, that in Tobruk the conditions were unique. The 2/4th A.G.H. was fully equipped, in spite of having recently suffered shipwreck, and not being able to hold patients long, really acted as a casualty clearing station. An orthopaedic table was part of the equipment, and the staff included surgeons skilled in this work. Without these special advantages the difficulty and often impossibility of applying a perfectly fitting plaster would have been a great drawback, as was found when the method was used in some other areas. The plaster was applied as a full case after the adjustment of a Thomas splint without extension. Except for the special advantages obtained in the use of this method for a journey of several short stages, there were drawbacks realised by Australian surgeons, but the subsequent modifications improved the control of the injury. In one of the later methods, "Elastoplast" extension was attached to the leg from the knee down, with a strip of felt round the ankle, and the whole was bandaged. A Thomas splint was applied with 15 degrees flexion at the knee and six slings. Extension tapes were tied tightly, but not strained, to the bar, and a light overall plaster was then applied, with a foot piece and sling from the bar of the splint. Such modifications were a matter of personal experience and judgment, and gave the patients considerably more comfort. It was, of course, recognised that the spica was not easy to apply, sometimes gave rise to trouble and was difficult to inspect with any satisfaction on a long journey; therefore it might produce sores. The so-called "Tobruk" plaster was a useful stage in evolution, still valuable in certain circumstances, particularly in its emphasis on immobilisation for purposes of transport. During the El Alamein campaign comfortable transport was obtained by the use of combined methods, such as a split plaster over strapping extension and a posterior slab, with a bent Thomas splint, the whole secured by a final complete plaster from groin to toes.

For treatment in hospital, three methods of handling were possible; the plaster spica, the bent Thomas splint with skeletal traction, and the straight Thomas with fixed extension. Pin traction was found efficient and satisfactory for reduction and maintenance of extension. Even in base areas the spica was not found as satisfactory as other methods. Muscle wasting and angulation of fragments made the fracture difficult to control in spite of the advantages of having the head of the bed raised to counter gravitational spread of infection up the thigh. The bent Thomas splint required the raising of the foot of the bed, with its disadvantage of upward spread of sepsis, with occasional pocketed abscesses. The straight Thomas splint allowed a flat bed and avoided this risk in a septic wound. These matters required the judgment of the surgeon and were determined to some extent by his own preferences. Where gravitational abscesses occurred, the risk to the patient's life had always to be considered and

sometimes the difficult decision of amputation was faced. Though adequate primary excision of wounds and the internal administration of sulphonamides controlled or prevented troublesome sepsis to a considerable degree, the risk of secondary bleeding was never absent. The advantages of treating all these patients in one ward were many, not the least of which was the supervision of the mechanical details, which contributed considerably to a good result. Individual attention is of course essential, even if it means devising modifications to meet special needs. A good example of this was described by Surgeon-Lieutenant H. B. Holmes, R.A.N.R., in which the incorporation of a steel plate in a body plaster and the use of tackle and counterpoise gave comfort and ease of nursing to a man who had multiple injuries of the right humerus, lumbar vertebrae, pelvis and both acetabula.

The position about the forward treatment of fractured femurs was well summed up by Colonel Hailes in a letter to Major-General Maguire, D.G.M.S., on the 10th April 1941:

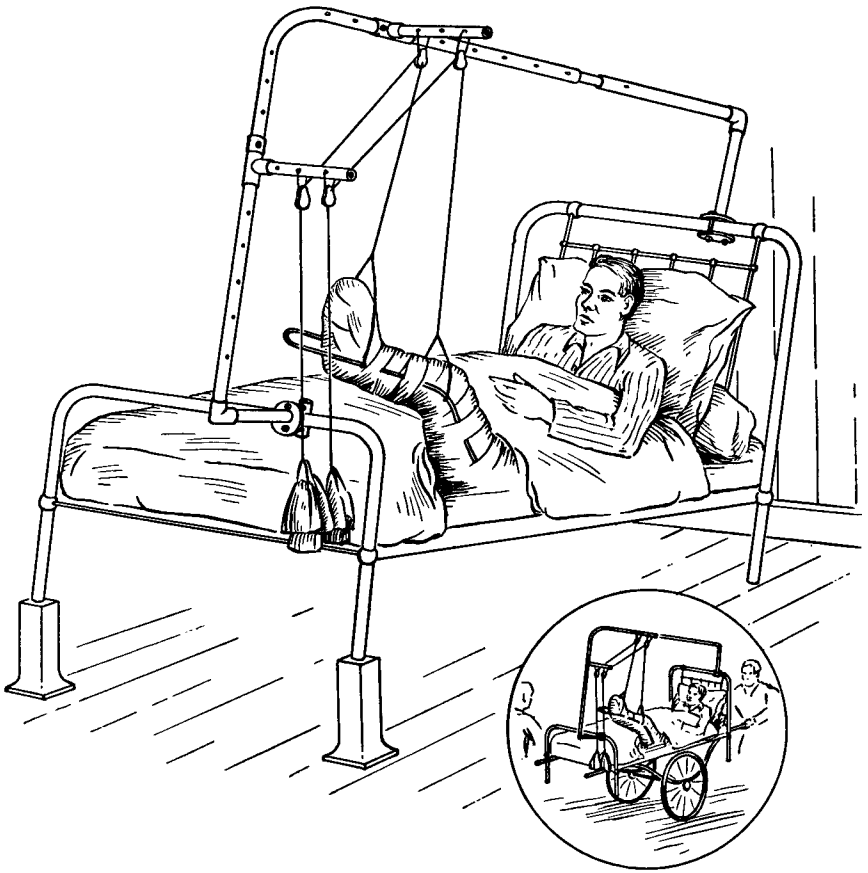
"The best results I have seen from the point of view of overcoming the difficulties of dangerous and trying carries are the plasters that have come from 2/4th Aust. Gen. Hosp. (Tobruk). Here an expert with plaster is directing the work and it is excellent . . . 2/1st C.C.S., on the other hand, has never had an extension table and works on the principle that it is better to send the femur down with a Kirschner wire extension for traction and the Thomas splint; in this case the extension is fixed extension to the end of the splint, that is, the Thomas splint used as it was originally intended to be used. These patients arrive at the base in good condition."

In the latter method, the splint was supported by being fixed to two suspension bars to prevent undue movement in a vehicle, each limb of the splint being separately secured to the horizontal and vertical parts of the suspension bars.

Certain cautions were necessary in the use of the Thomas splint. The danger of employing a clove hitch was real, as ischaemia of the foot could easily be produced. A clip or pin on or through the boot was safer, but no such methods of fixation were permitted until the man reached a main dressing station.

Keon Cohen reviewed 32 cases of fractured femur in the 2/7th Australian General Hospital in Palestine during a later period, from May 1941 to June 1942, 14 being compound fractures of the neck or shaft of the bone. These patients were transported to hospital in various ways. In Syria, the front line first aid consisted of tying the legs together to a rifle or to the stretcher. The journey to base was made in a Thomas splint, and, with the help of a relatively short journey over good main roads or by hospital train this secured reasonable comfort. Experience showed that if fixed extension caused pain, the extension was faulty in application. The danger of a clove hitch just mentioned was apparent during the brief period of this campaign. This method, with the use of the Thomas splint, was not vaunted as ideal or always as effective for transport as the "Tobruk" plaster, but it was very satisfactory if properly applied. Even with a short distance from field ambulance to hospital some half dozen men in plaster

had pressure sores on arrival, necessitating removal of the plaster on admission. As a warning, it is well to record that one patient, not from an Australian unit, arrived in a long Liston splint, which completely failed to immobilise the limb, as might be expected. In hospital, Thomas splints were used with Balkan frames and the necessary gear for traction. This allowed functional activity to be maintained and good results followed. Doubt was felt now and then whether to immobilise patients who were to be returned to Australia in the immediate future; usually this was regarded as the wiser course.



Modified Balkan beam, Palestine 1941.

Special care was necessary in excision of wounds of the thigh; not only was there risk of loss of the limb, but also of life. Both wounds of entrance and exit were advisedly excised widely, so that the fracture site could be seen from both aspects of the thigh. The *fascia lata* was included in this operation; not merely a slit was made, but an oval incision was made so that the edges could not fall together. Sometimes it was found that a

certain degree of compromise was advisable, as patients in poor condition did not always stand extensive procedures well.

A surgical lesson of the first two years of war was that in the treatment of wounds of the lower extremity the requisites were adequate resuscitation, adequate excision and rigid immobilisation. Considerations of time, place and transport may modify methods to some extent, but in particular no patient should leave without his limb properly immobilised, yet without its circulation being jeopardised. Exact alignment was of less importance. No complaint of specific discomfort by a patient should be disregarded.

In hospitals the treatment had only begun when the limb was slung in a Thomas splint and extended by skeletal traction, or immobilised in a Thomas bed knee splint with fixed traction, or in a spica. Constant care was necessary in nursing and all the ingenuity of a mechanically minded surgeon. In base hospitals in Australia later some difficulty was experienced in obtaining calliper splints promptly to measurement. This was overcome by providing four sizes of rings and adjustable side pieces.

When campaigning began in New Guinea great difficulties in transport of patients were encountered. In the fighting on the Owen Stanley Ranges litters were the only means of moving seriously ill men, and units able to hold these patients, even for brief periods, were forced to extemporisation. Until airstrips were available patients were held, sometimes for several weeks, in daily hope of air evacuation, and during this period weight traction was not employed owing to the possible need of moving the men at very short notice. At Myola, 6,500 feet above sea level the area was relatively clean and plaster spicas of the hip were used with safety. Some of these had to be left on too long owing to delays in transport, but fortunately anaerobic infections were not a problem there provided due care was taken to ensure good blood supply. Eventually the patients had to be carried back to Kokoda whence they were flown back to a base hospital in the Moresby area. Under these conditions, without X-ray facilities in these difficult forward areas, mal-union and skin ulceration could not always be avoided, but the great majority of the patients made satisfactory recovery. When the scene changed to the muddy areas from Soputa to the coast, heed was taken of the numbers of anaerobes found in these wounds, and Thomas splints were used by preference. In the following Wau campaign the surgical consultant agreed with surgeons in the forward teams that plaster was unsafe. Now that all practical details in the use of the Thomas splint were routine procedure, there was the added advantage of speed, with thereby lessening of shock. The plaster spica is unsuitable in humid climates. Atmospheric moisture and sweating hinder drying of the plaster, and lifting and moving the patient cause ridges to form in the case. Not only is the patient uncomfortable but pressure sores form insidiously and rapidly. Another important consideration was that of weight. Yeates pointed out that one Papuan boy could carry seven Thomas splints, but only enough plaster for two spicas. Besides, the application of a spica in a small dressing station with poor facilities was a trying procedure. The splint was lashed to the cross piece at the

foot of the stretcher with the ring fastened to the side pole. Practically all the men with fractured femur were sent back by air across the mountains to Moresby in Thomas splints with strapping extension. Similar methods were also found advisable for difficult land stages on the route to the base, as they allowed for ready inspection of the wound if made necessary by unavoidable delays. Where the fracture was sited too high for control in this way a plaster spica was used.

During later campaigns the same general principle was maintained of taking all local conditions into account when selecting technical methods. In the handling of injuries involving much damage of soft tissue there can be no doubt that adequate surgical measures taken in forward operating units prevented gas gangrene and other severe forms of sepsis to a great degree.

In the later campaigns on the north coast of New Guinea the risks of infection were clearly recognised, and excision of wounds was carried out promptly and boldly. It was admitted by competent surgeons, however, that the decision as to how radically "excision" should be carried out was not always easy to make. Some doubt was felt as to the sterility of sulphanilamide powder in the Salamaua actions where it was supplied in paper bags, but no trouble occurred. Plaster spicas were used there only for high fractures, and in addition to other drawbacks difficulty was experienced in drying the plasters in the steamy heat. Native bearers took patients gently and safely over the most precipitous tracks in this campaign. At Aitape also Thomas splints were found satisfactory for the control of fractured femurs, even during transport.

Before penicillin became freely available in the field and lessened the risks of chronic bone sepsis, serious consideration had been given to the treatment of established sepsis in fractures of long bones, chiefly the femur.

Though not so high a proportion of fractured femurs were seen in the first few years of war as in the 1914-1918 war, owing to the relatively high number of injuries to the leg below the knee from land mines, these injuries were a serious challenge to surgery.

Treatment was well standardised. By 1943 with the experience of the Middle East and New Guinea, treatment consisted of excision of the wound, drainage, the use of sulphanilamide and light packing of "Vaseline" gauze and immobilisation in plaster. This method was really restricted to two conditions, where difficulties of transport existed, and where a gunshot wound of the thigh was recent and in which sepsis of bone had not occurred.

Harley Turnbull described observations and results of treatment in Concord Military Hospital. Where bone sepsis had become established plaster had little place in a base hospital. Turnbull stressed the important factor of physical and mental stamina, sadly sapped in these sufferers from established sepsis. In a ward full of men in foul smelling plasters the atmosphere was one of defeat. General treatment was important; investigation of the blood sometimes showed a fall in protein content, and anaemia with low haemoglobin values was likely. A rich diet, with abundant protein,

and vitamin *C* particularly were needed. Mental rehabilitation was most important, here occupational therapy was essential, and physiotherapy also, aimed at maintaining a good muscular and vascular function in unaffected parts of the body. Immobilisation was usually maintained with a bent Thomas splint with weight extension on a frame. Gravitational abscesses occurred in spite of care and needed dependent drainage. Sequestra when demonstrated by X-rays needed removal, preceded by dosage with sulphonamide if any surgical intervention was necessary. B. K. Rank, writing of chronic wounds of bone, summarises the plastic surgeon's views as follows:

"With long-standing sepsis and sequestration common to the open comminuted gun shot wound fractures, bone sclerosis has much the same effect as fibrosis of soft tissue wounds, producing discharging chronic wounds biologically incapable of healing. Up till 1944, many of these found their way to plastic units at periods long after their injury. Large numbers of bone cavities were treated at this late stage when radical methods of plastic closure were the only alternative to a lifelong disability. Many of these cases were treated in the Repatriation Department for years following the last war. Saucerisation of the bone cavity was widely applied, in preparation for epithelial inlay graft at a later stage. It is now considered that results for these procedures are satisfactory for smaller cavities in some situations, but not for large cavities in the vulnerable below-knee areas; and, moreover, the amount of bony continuity in such cases is often inadequate for normal weight-bearing. In these circumstances, we have regarded healing by an inlay as a palliative during the migration of a skin and fat flap from the abdomen or from the other leg. After this, cancellous bone grafts were freely applied.

"With penicillin, procedures on these lines were done much sooner, and in the last phase, many chronic wounds were prevented by application of plastic principles to cover bare bone in early treatment. Even in the base plastic units, many of the type wounds which would have previously ended up as chronic bone cavities were treated much earlier by radical preparation and flap migration after control of sepsis by penicillin. So the chronic bone wound is also disappearing as a major problem."

The influence of penicillin has perhaps now somewhat obscured the difficulties of the earlier period, and has tended to underrate the value of sulphonamides and of antibacterial drugs.

The aminoacridines in particular have played an important part in the treatment of wound infection, and in spite of the spectacular success of penicillin and the undisputed value of sulphonamides within their own field, they still had a place at the end of the war, though none could prophesy further developments of antibiotics. Mention is made elsewhere of the difficulties raised by the creation of penicillin—and sulphonamide—resistance in bacteria. Further details of the aminoacridines are given in another section.

As a result of promising laboratory results clinical trials of aminacrine hydrochloride were made in 1943 in the 113th Australian General Hospital, Concord, later known as the 113th (Concord) Military Hospital, by Group Captain H. R. G. Poate. A solution of 1 in 1,000 was found active and not appreciably injurious to tissues, and did not prevent phagocytosis. Poate treated 24 patients suffering from severe gunshot wounds of the bones in which sepsis was long established. The wounds were irrigated and then dusted with "Monacrin" (aminacrine hydrochloride) and

Carrel tubes were used for subsequent periodic irrigation with a 1 in 1,000 solution, at first for four hours a day and later for two hours a day. As the wound cleared an emulsion was substituted, secondary infection being prevented by the use of greaseless ointment on the skin.

This routine produced excellent results. On other wounds mixtures of "Monacrin" powder and sulphanilamide in proportions varying from 1 to 40 and 1 to 100 were used with success. The former strength was found appropriate for pre-operative treatment in facio-maxillary wounds and the latter for fresh traumatic wounds, in each case one application only being used.

Turnbull found that this method gave chemotherapeutic control of infection in wounds affecting long bones, and provided the fourth requirement, the other three being immobilisation, dependent drainage and prompt removal of dead bone. Within 48 hours control of infection was accomplished. Arden also reported good results with recent traumatic casualties in children, and was able to avoid excision of bruised or lacerated tissue by infiltration with aminacrine solution.

The introduction of penicillin greatly decreased the morbidity and mortality of serious injuries of the thigh; indeed the surgeon's capacity to immobilise gunshot injuries of the extremities marched *pari passu* with chemotherapy. At the 2/11th A.G.H. at Aitape in 1945 gunshot wounds of smaller bones were being closed without sepsis, and of thirty gunshot wounds of the femur only three showed sepsis, which was but minor in degree. Firm union was obtained in these after ten weeks of immobilisation with extension.

Majors T. F. Rose and A. L. Newson published the results of a series of 126 compound fractures of the extremities due to gunshot wounds. First treatment was given in forward surgical units and continued in army general hospitals. This report was concerned with the healing of soft tissues and not with end results of function, but with due regard for both of these aims once wound healing could be reliably accomplished the rest should follow. The wounds were received in jungle fighting. Some of them were of destructive nature with shattering of bone, and effusion of blood under fascial planes was common. Emergency splints were applied and oral administration of sulphamerazine was begun. When the man reached the operating unit penicillin was given, 15,000 units intramuscularly every three hours. Tetanus toxoid and gas-gangrene antiserum were given as a routine. Resuscitation was usually required: a litre of blood was given in twenty minutes and then the rate slowed till the patient was ready for operation. Siting of foreign bodies and the state of bony structures were ascertained by X-ray examination. "Pentothal" anaesthesia was used and the usual routines of excision followed. Penicillin-sulphanilamide powder was insufflated into each wound. Primary suture was performed if justified by all the conditions, and if observation for a week was possible. If not, wound revision was carried out four or five days later, and delayed primary suture or secondary suture with any further necessary resection performed at the appropriate time. Where skin loss was great temporary

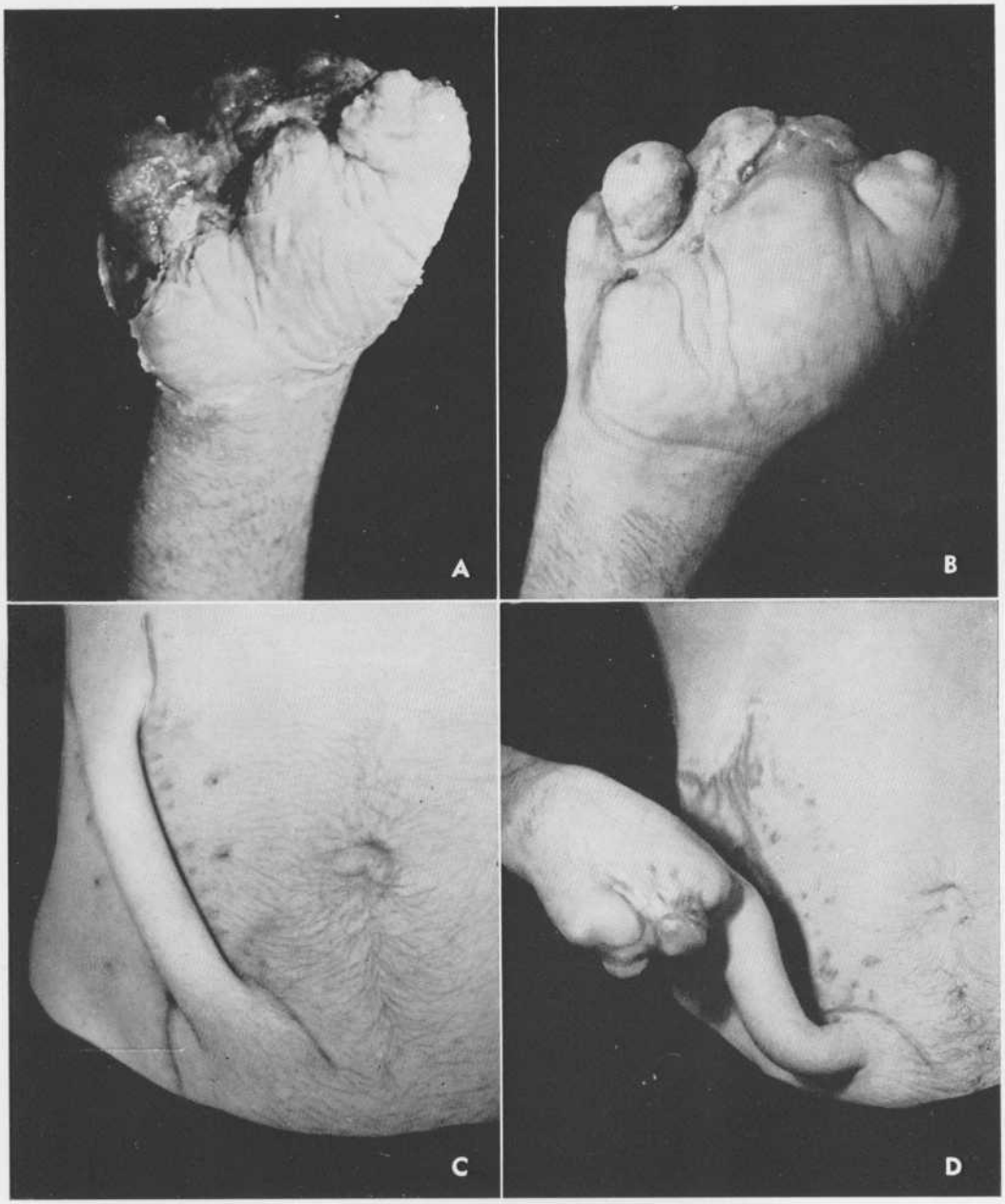
grafting was done where possible. No instillation of penicillin through tubes was practised in this series so as to avoid secondary infection and the creation of resistant strains.

Infection of wounds occurred in some instances, and further surgical measures were occasionally needed, "Monacrin" was used and found very efficacious in established infection and in wounds where suture must perforce be delayed. Penicillin was continued parenterally in every case till it was evident that infection was not likely to occur, or if present was controlled. In the handling of the actual fractures immobilisation was regarded as vital: alignment was of secondary importance, and no internal fixation was used in this series. Plaster casts were found to have the disadvantage that secondary invasion by staphylococci and Gram-negative bacteria occurred unless windows were used for inspection. Results were very satisfactory. Of the 126 wounds, 31 healed without excision; 31 were treated by primary suture, with 27 successes; 29 out of 30 delayed secondary sutures, and 9 of 11 secondary sutures succeeded, suture after five weeks was performed in 12 cases, and 11 amputations were necessary. Seventeen wounds were infected, 11 of these after excision, chiefly by a penicillin-sensitive *Staphylococcus aureus,* but the cause in each case was the presence of necrotic material. No blood infections, or severe sepsis or gas gangrene occurred.

These results reflect the improvements which were obtained in all units when the parenteral use of penicillin was added to the standard surgical measures in forward areas. Provision was made for the giving of sulpha drugs and, if possible, penicillin during the patient's journey to a general hospital, which, ideally, should be reached within seven days of wounding. There the blood chemistry was investigated, necessary general measures were taken, and then the wound was treated. Penicillin allowed secondary suture to be done safely up to an interval of seven days, with further excision is necessary. The conversion of an open to a closed fracture is a most important step. Further movement of the patient to a base area could safely be made in 10 to 22 weeks when wounds had healed and sufficient union made transport safe.

The next step in treatment of long bone injuries was the use of internal fixation. The introduction of vitallium was an important adjunct to this method. This alloy of cobalt, chromium and nickel is electrically neutral, and is not corroded within the body. It was scarce, and plates and screws often had to be removed, not because of local irritation, but because they were needed for further service.

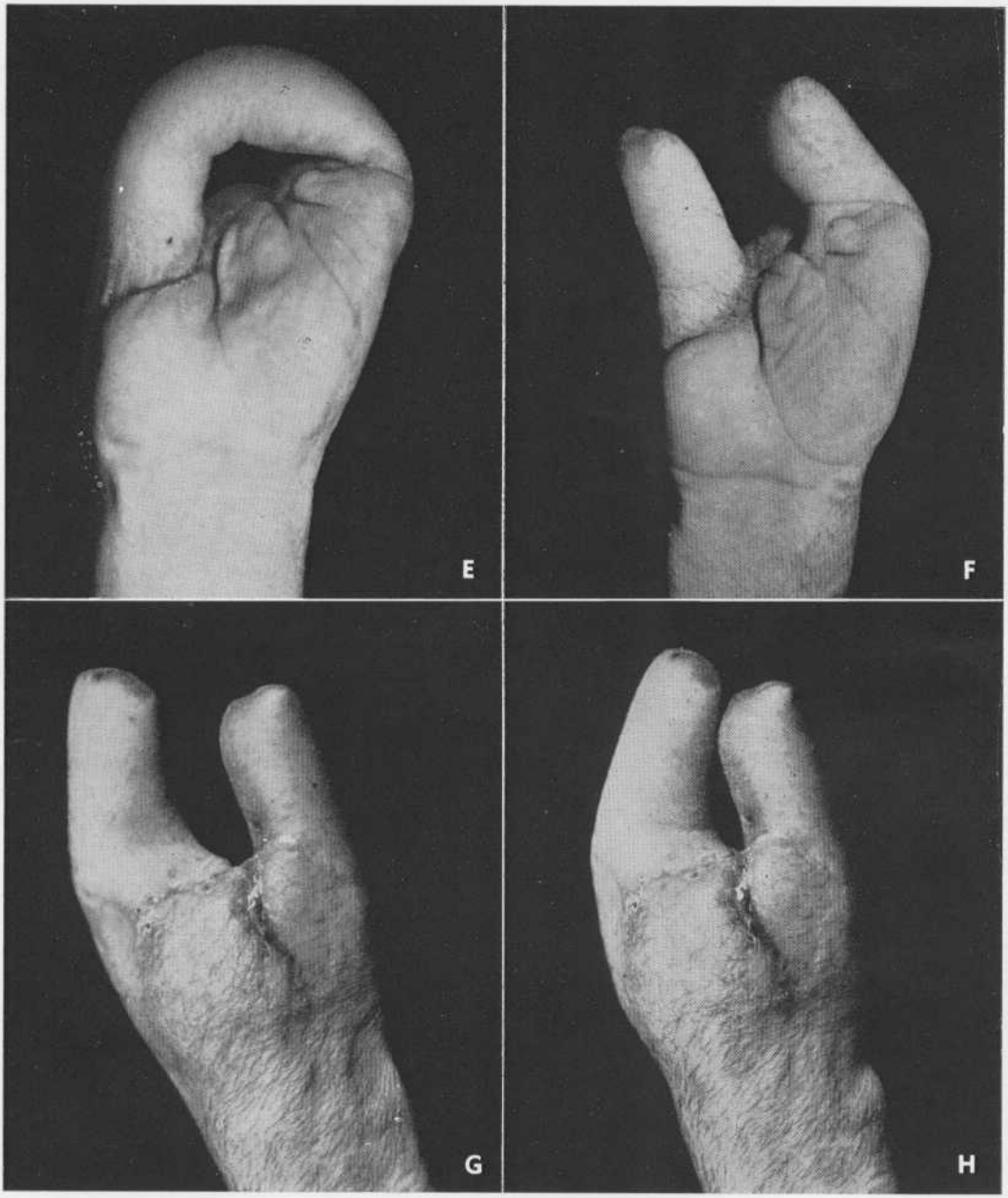
Towards the end of the war the more favourable conditions particularly of transport in campaigns like those in Borneo allowed full use to be taken of the advantages of penicillin. In the forward areas the same methods were used as previously, with some local modifications. Thus at Balikpapan unilateral spinal analgesia was found satisfactory for reduction of fractures of the lower limb; Kirschner wire extension and plaster were used for immobilisation. At forward bases the safe use of mechanical



(B. K. Rank)

Reconstructive surgery for the severest hand mutilations.

(a) An extreme hand mutilation—the thumb metacarpel and some thumb muscles are intact.
(b) The healed wound. This is not accepted as an end result.
(c) and (d) Stages in digital reconstruction using an abdominal pedicle.



(B. K. Rank)

Reconstructive surgery for the severest hand mutilations.

(e) and (f) Cancellous bone graft pegged into metacarpal remnants.
(g) and (h) The final result showing the useful range of movement. Much better than (b) or any prosthetic aid.

fixation of fractures of the long bones "covered" by penicillin was demonstrated towards the end of the war.

K. W. Starr, in recounting his own experiences, has pointed out that the surgical pathology of fractures must be considered in reviving the work of Lane and others of almost two generations ago. Penicillin, and to a less degree modern antiseptics, have permitted the almost non-reactive vitallium plates and screws to be used with greater safety. A combination of resorption and callus formation must have full play before repair can take place. Resorption is impeded by the natural obstacles of a compact bone structure and solid trabeculae, and also by infection which will devitalise cells and impede their essential functions. Established infection in compact or bare cancellous bone cannot be eliminated by immobilisation and chemotherapy, but its duration is much reduced if cancellous tissue is cleaned out and the cavity filled with cancellous grafts and covered with plastic flaps. The hazards attendant on the union of a compound fracture are inadequacy of immobilisation, of blood supply, and of the area of the fracture site, infection and the interposition of soft tissues. It is, of course, ideal if immobilisation may be assured without risk, and this risk depends on the presence of infection. A minor difficulty is that the absence of electrolytic influence on the tissues by vitallium cannot be relied upon in the presence of sepsis. The methods of fixation used in Starr's series were the insertion of Steinmann's pins in appropriate locations, wiring, and plating. Only the last mentioned was found satisfactory in most fractures of long bones.

During the Borneo campaign Starr treated at a forward base 40 wounds involving long bones by fixation, operation being carried out at the time of delayed treatment, three to seven days after wounding. A high degree of penicillin level was attained in the blood before operation. When wounds could be closed, a penicillin-sulphonamide powder was left in, when they were left open irrigation with 1 in 1,000 "Monacrin" solution was employed. Once infection was controlled the dead white bone end was drilled in a number of places usually within a week of fixation, and the plate was left till union was firm. It was found advisable to remove the plates then, usually after 12 to 16 weeks, but when fixation was carried out as a primary measure this was not necessary as a rule. Removal was practised in these rather because of the shortage of vitallium plates which had to be reclaimed for further use. Out of about 500 fractures 122 were treated by fixation.

Wounds involving the tibia and fibula were sometimes troublesome. In the desert serious injury of the feet and lower legs were not uncommon, and these were seen in the islands also. Fractures of the *os calcis* were sometimes seen in men standing on the deck of a ship subjected to bombing from the air. In the *Orion* returning from Crete a number of such injuries occurred.

The lesser injuries of the lower leg during the later phases of the war were satisfactorily treated by closure with the help of penicillin, but some of the most difficult problems were presented by comminuted fractures of

the tibia, especially when associated with great loss of skin. Infection was likely to occur in wounds of this class, in which thorough removal of foreign bodies and devitalised tissue need care and time.

In attempting to sum up the treatment of compound fractures certain principles may be laid down. Definitive treatment should be undertaken in the field in an area sufficiently forward to ensure that the wounded reach surgical aid without being subjected to too long and trying a journey. Such a surgical unit needs to be so sited as to permit reasonably comfortable and not unduly hazardous working conditions. The Thomas splint still stands as the mainstay for external immobilisation of most fractures of the femur, but good facilities for plastering should be available, as the combination appears ideal for purposes of transport. Internal fixation can be safely done in clean wounds with or without drainage according to circumstances, and even in the presence of infection as an adjunct to continued treatment, provided free drainage is maintained. Whether the infected fracture is mechanically fixed or simply drained is for the judgment of the expert surgeon. It is of course necessary that facilities should exist at the operating centre for skilled surgery, and for retention of the wounded under good nursing conditions for sufficient time to make further travelling safe and humane. War experience has shown that immediate internal fixation of compound fractures even of the lower extremity can be safely done if the wounds are clean. The great advantage in internal fixation is the perfect immobilisation attained, with all its concomitant advantages. Where immobilisation was complete sepsis and secondary haemorrhage were not serious problems. External fixation is necessary in any case in addition, at least for some weeks, and has the merit of securing rest and non-movement of the injured soft tissues.

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CHAPTER 39

WOUNDS OF JOINTS

THESE injuries called for great skill and initiative, as the official technical instruction (No. 22, Middle East) pointed out. The surgical principle of keeping the joint immobilised in its natural position of rest was not simple to carry out. In order to immobilise the knee joint, the whole lower extremity had to be controlled, and the special instructions laid down that either a plaster spica was used, or a plaster casing from the groin and gluteal fold downwards over a Thomas knee splint slung from a frame. Sepsis of the joint introduced a grave problem, for immobilisation, so necessary in this very painful condition, was more difficult to maintain. Suppurative arthritis with its accompaniments of fever, toxaemia, anaemia and local abscesses or generalised blood infection was still found to be a formidable illness. Experience discounted some of the earlier optimism which expected the natural powers of resistance, aided by immobility in plaster to overcome this type of infection. The decision whether amputation was necessary or not was just as important and difficult in some of these infections as it was during the 1914-1918 war. Experience with bullet wounds was more favourable than with those produced by more destructive missiles; rest and the minimum of interference produced good results. Excision was reduced also to the minimum; as a rule only the wound of exit needed attention, chiefly if the bullet, after striking bone, had been deflected. Aspiration of the synovial space was sometimes necessary. Usually active movement could be begun in two or three weeks, provided the bones were not seriously damaged. The larger wounds, from shells, particularly those with lodged foreign bodies, were much more serious. In forward areas the lack of X-ray facilities made this work difficult. It was somewhat a question of transport, and in the later years when the conditions of the terrain or the provision of air transport permitted it, a delay of two or three days before primary excision of the wound was undertaken permitted fuller investigation to be made under good conditions. The developments of chemotherapy made this a much safer procedure. By giving the patient a better chance of functional recovery penicillin encouraged adequate exploration, search for and removal of foreign bodies, and excision of devitalised tissue.

The need to save life was a real one in wounds involving large joints, and resuscitation was needed by all patients with such severe injuries whether their appearance at first suggested it or not. Actual loss of blood as in all severe limb wounds was often considerable, and serum or plasma alone was not always enough.

Major T. F. Rose and Major A. L. Newson have reported a representative series of 66 gunshot wounds of the limb joints seen in the later Pacific campaigns. They recognised three types of wounds, one in which the capsule and synovial membrane were perforated or torn, one in which

the bone and the articular surfaces had been injured, and one in which complete disorganisation of the joint had taken place. In the latter types injury to nerves and blood vessels was sometimes an additional major complication. No less than 40 of the severest variety of injury were included in the series; in these nothing better than ankylosis could be expected as an end result. As a routine sulphamerazine was given by mouth when first aid measures were applied, and as soon as possible penicillin, 15,000 units every three hours, was administered, as well as gas-gangrene antitoxin and tetanus toxoid. Radiological examination was made when possible. High-velocity missiles produced less damage than those of lower velocity and the resultant wounds often did well with merely aspiration of the joint and instillation of 20 c.cm. of penicillin solution, 5,000 units per millilitre. Where soft tissue damage had occurred excision was carried out and in the search for foreign material another incision was sometimes necessary. When severe damage had occurred all loose fragments were removed, including articular cartilage, if it was obvious that ankylosis would occur. The patella was saved if possible in injuries of the knee joints, as it was felt that minor damage did not justify the removal of this bone as some advise. Capsular suture was done in large joints where the conditions permitted, and penicillin was introduced before the last stitch was tied. Where damage was so severe that no repair could be made the wound down to the joint space was lightly filled with gauze soaked in 1 to 1,000 "Monacrin": this could be left for two or three days undisturbed. If X-ray examination was not at first available it was carried out as soon as possible, and if intra-articular foreign bodies had previously not been located they were removed by the most suitable route and penicillin was again instilled. Where early suture was not possible the matter was reviewed after four or five days. Some wounded men reached the surgeon only after the lapse of several days, when infection was already established. Such infections were treated according to the indications, drainage being ensured by wide incisions if necessary. A problem sometimes arose when evidences of infection of a joint cavity occurred after closure. If no foreign body was present and if the effusion was not purulent, aspiration and redosage with penicillin locally might suffice. More radical measures were sometimes inevitable, but where severe spreading sepsis occurred no attempt was made to perform resection. Amputation of limbs was performed at the primary operation in 18 of this series; it was necessary later four times for spreading infection. Special mention must be made of the tarsal and tarso-metatarsal wounds, which are apt to be troublesome. In two cases of this series amputation was required; in the remainder the tarsus survived infection, but no details as to ultimate functions were available at the time. "Monacrin" was found useful as a local application as in the wounds not involving joints. The dosage of penicillin was that found effective in other deep tissue wounds. In spite of the capacity of the antibiotic to enter serous cavities from the general circulation its local introduction into the synovial cavity as above described was thought desirable. Tube instillation was not used.

Immobilisation was ensured by the usual methods: when infection of joints was present light traction on a strapping extension was applied to keep the joint surfaces apart.

The simplest evaluation of the results is in the authors' words "now that penicillin has minimized the effects of pyogenic cocci and anaerobes, and local 'Monacrin' therapy that of the Gram-negative penicillin resisters, the ultimate result is in direct proportion to the structural damage". This is borne out in the retention of good movements in injuries of the two lesser types, and the successful localisation of sepsis in most cases. It is interesting that one Japanese prisoner developed tetanus which was successfully treated. Careful attention was given to mobilisation of the joints: early movement was possible in lesser injuries, if pain was disappearing, but the decision in these matters must always be individual.

When patients were moved to bases on the mainland at a stage when movement was essential, difficulties were experienced in securing regular muscular exercises and mobility of joints during a long and often interrupted journey. Owing to unavoidable delays, patients sometimes arrived at the 1st Australian Orthopaedic Hospital at Toowoomba with stiff joints. The establishment and maintenance of an orthopaedic hospital belong to the administrative side of the history: here it may be stated, however, that some surgical opinion considered that under prevailing conditions of distance and transport, special departments attached to general hospitals were more generally useful.

In other areas similar results were obtained, and experience laid emphasis on the necessity for thorough exploration of these wounds for foreign material, without which reliance on penicillin was destined to failure.

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CHAPTER 40

ORTHOPAEDIC SURGERY

DISABILITIES OF THE FEET

THE surgical care of the feet devolved largely on orthopaedic surgeons in general hospitals, and the principles laid down there were diffused through the whole force by a process of education. At first, the importance of careful examination of the feet on enlistment was not as clearly realised as was desirable, but schools for medical officers and the circulation of official instructions helped to prevent the admission of recruits with disabilities of the feet. *Hallux valgus* and *rigidus,* hammer toes or deformities of the toes, dropping of the transverse arch, inability to reconstitute a fallen longitudinal arch, and *pes cavus,* were conditions of importance under service conditions, yet unless the presence of callosities drew attention to them they might go unrecognised in their milder forms. There is no doubt that all care should be taken to ensure the orthopaedic fitness of recruits for the Services. The establishment of foot clinics in the A.I.F. was begun in Palestine by Major R. V. Graham. One of the important functions of this clinic was the diagnosis and, if possible, correction of lesser degrees of these disabilities so as to make the men with them able to undertake ordinary military duties. This depended in part on the proper selection and fitting of the army boot to the soldier's feet.

The experience of the First A.I.F. was valuable in this matter of securing properly fitting boots, for the 1939-1945 war started with a correctly designed boot. This was made on a last differing from many of those either selected or suffered by the civilian in being shaped like a human foot, but had the drawback that it was often too narrow. A firm block toe protected the toes and when correctly chosen and fitted and "broken in" so as to ensure comfort around the ankle, this boot was very satisfactory, at least in the dry climate of the Middle East. Much of the trouble with boots arose from allowing the soldier to choose a pair which he thought fitted him which were almost invariably too small. It must be admitted, however, that adequate supplies of boots sufficiently broad were hard to obtain. A check in one field ambulance showed that 50 per cent of soldiers were wearing boots too small for them. In another test reported to I Australian Corps, 425 men out of 609 wore boots that were too short. It seems obvious that a boot meant to be worn by "man upright" and used for locomotion should not be fitted in any other position than the erect stance, and preferably with the wearer carrying a full pack. The official instructions clearly laid down the methods of measurement and fitting of boots in a special manual (*Fitting of Boots and Care of Feet*) but these were not always followed.

Both medical and combatant officers who conducted foot parades often found a surprisingly high percentage of men with avoidable trouble with

their feet. Though it is recognised that every good company officer should be interested in men's feet, it would be good if the principle were generally adopted. It does not follow that officers themselves selected correct shoes or boots.

It is interesting that the first women to leave Australia with the A.I.F., nurses for a general hospital, had shoes supplied on private contract without safeguards for correct lasts or fitting. The results were bad, for the shoes were quite unsuitable and were pronounced as orthopaedically quite incorrect by the hospital orthopaedic surgeon. Similar troubles occurred with shoes supplied for members of the women's services later in the war, and were only composed by the work of a combined committee which at last succeeded in having supplied shoes which were comfortable and scientifically correct. Wider fittings were needed. In some areas, for instance, where numbers of country girls were enlisted and in hotter climates such as Queensland, a larger and wider shoe was essential. In one base postal unit servicewomen had considerable trouble with their feet as they had to stand on concrete floors; some relief was obtained from rubber heels.

The various disabilities of the feet seen at a unit aid post were described by Captain R. S. Lahz. Ingrown toe nail, hammer toe, bunions associated with *hallux valgus,* corns of the fifth toe and deformities of this toe, were not uncommon. Flat-foot was of significance when the foot was pronated with signs of arthritis in the talo-navicular joints, or if swelling, pain and tenderness of the arch were present. These disabilities made a recruit unfit, at least temporarily. Exercises were found of considerable value. Tenosynovitis of the *tendo Achillis,* sprains of the ankle with post-traumatic pain gave trouble, and static conditions like bony bosses or spurs and adhesions in the small joints were also seen. Calluses due to various deformities or ill-fitting boots required corrective treatment as well as immediate relief.

Squadron Leader D. Barry described similar conditions in the Royal Australian Air Force, with the addition of *pes cavus,* examples of which occasionally slipped into the services. Concerning this and other disabilities Colonel W. A. Hailes, Consulting Surgeon to the A.I.F., wrote as follows:

"*Pes cavus* is a serious disability, more to be feared than flat feet, and the early stages of it are not so well recognised. Cases that are considered so advanced that they require operative treatment should, in my opinion, be boarded C2 and returned to Australia—these cases should not be operated on in the Middle East or in operational areas. A certain number of cases of *hallux rigidus* and *hallux valgus* have been operated on, and we know that, initially, the results were satisfactory. A number of these cases have now been discharged from hospital after at least 7 months or longer, and the records are being consulted to see what real soldiering these men have done since operation. It cannot be too strongly emphasised that toes are of value and should not be removed, they should, if deformed, be arthrodesed or filleted. A displaced or deformed toe may need treatment; fillet it or arthrodese the joints and leave it straight—only as a last resort should a toe be removed. In such common conditions as hammer toe or displaced little toe, if one is removed, not only is its function lost, but one or two more become out of place, and so it goes on."

When jungle training was initiated numbers of men who had gone through campaigns in the Middle East had trouble with their knees or feet. The problem of patching up these men or alternatively of regrading them to a lower class was not always easy to solve. Some of these men suffered from cumulative strain on the feet, probably accentuated by the hard conditions imposed by a hot humid climate, which in itself was most destructive on footwear.

Special mention must also be made of the "stress" or "march" fracture. These stress or fatigue fractures were not very uncommon. The second metatarsal was the bone commonly affected, and fracture occasionally was found after a surprisingly small amount of strain and trauma. Though men achieved great feats of endurance in marches in fighting order there were those who, usually early in training, demonstrated by a breakdown of this kind how little practised the human foot is in its correct function. Collapse of the ligamentous structures of the feet under strain was an occasional cause of unfitness also; it has been previously mentioned.

At the foot clinic at the 2/1st Australian General Hospital schools were instituted for chiropodists. The consulting surgeon in a letter to the D.G.M.S. described this work as follows:—

"The work that Major Roy Graham has carried out in training chiropodists has been of inestimable value in that, in each unit, one man is trained to see that each soldier's boots fit, that the boots issued to the soldier are not just the correct size numerically, but actually fit him according to accepted standards. These men are also trained to teach and supervise the exercises that are necessary to control early cases of dropped anterior arches and flat feet. Correct fitting boots and exercises conscientiously carried out will result in most of these early cases retaining their efficiency and carrying on. It should be emphasised that any of the above mentioned conditions or any other foot disability associated with corns or callosities, should be rejected. Potential soldiers so affected, should only be accepted if exercises conscientiously carried out materially improve the condition, if improvement has occurred and callosities disappear; this is almost a gauge of progress; it will take about two months to achieve an appreciable improvement. The work of the chiropody Cpls., most of whom have been trained by Major Graham, has done a great deal towards maintaining the efficiency of many soldiers with mild degrees of these distressing disabilities. The full co-operation of these N.C.O.'s is to be aimed at, both at the regimental aid post for instruction and supervision and foot exercises, and at the Q.M. store whenever a pair of boots is issued."

A comprehensive instruction was issued on disabilities of the feet and indications for treatment (appendix). It should be noted that the results of treatment for ingrowing toe nail and bunion were not always found as satisfactory as was originally hoped. It must of course be admitted that a correctly performed operation could be negated by incorrect treatment of the feet later.

INTERNAL DERANGEMENTS OF THE KNEE JOINT

Major R. V. Graham reported the result of 128 operations performed at the 2/1st Australian General Hospital in Palestine over a period of one year from 1st June 1940. From this date a modern operating theatre was available, though only tented wards were in use till paved huts were



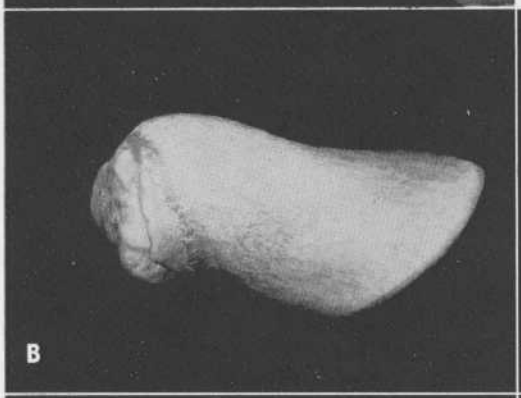
Treatment of unhealed amputation stump at a base hospital.

(a) (b) and (c) Palliative skin grafts effect sound healing before elective re-amputations are considered. In the pre-penicillin days re-amputations were best postponed until stumps were soundly healed.

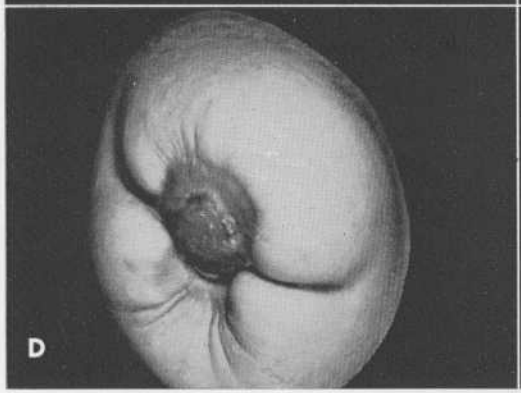
(d) A typical chronic wound of an amputation stump with granuloma over the bone end.

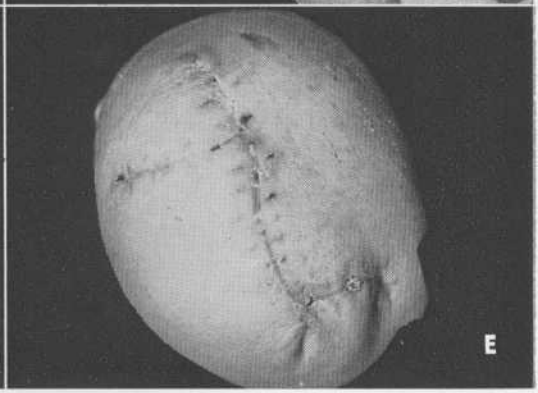
(e) The same stump after bone shortening and plastic repair of the unhealed stump under penicillin "cover".

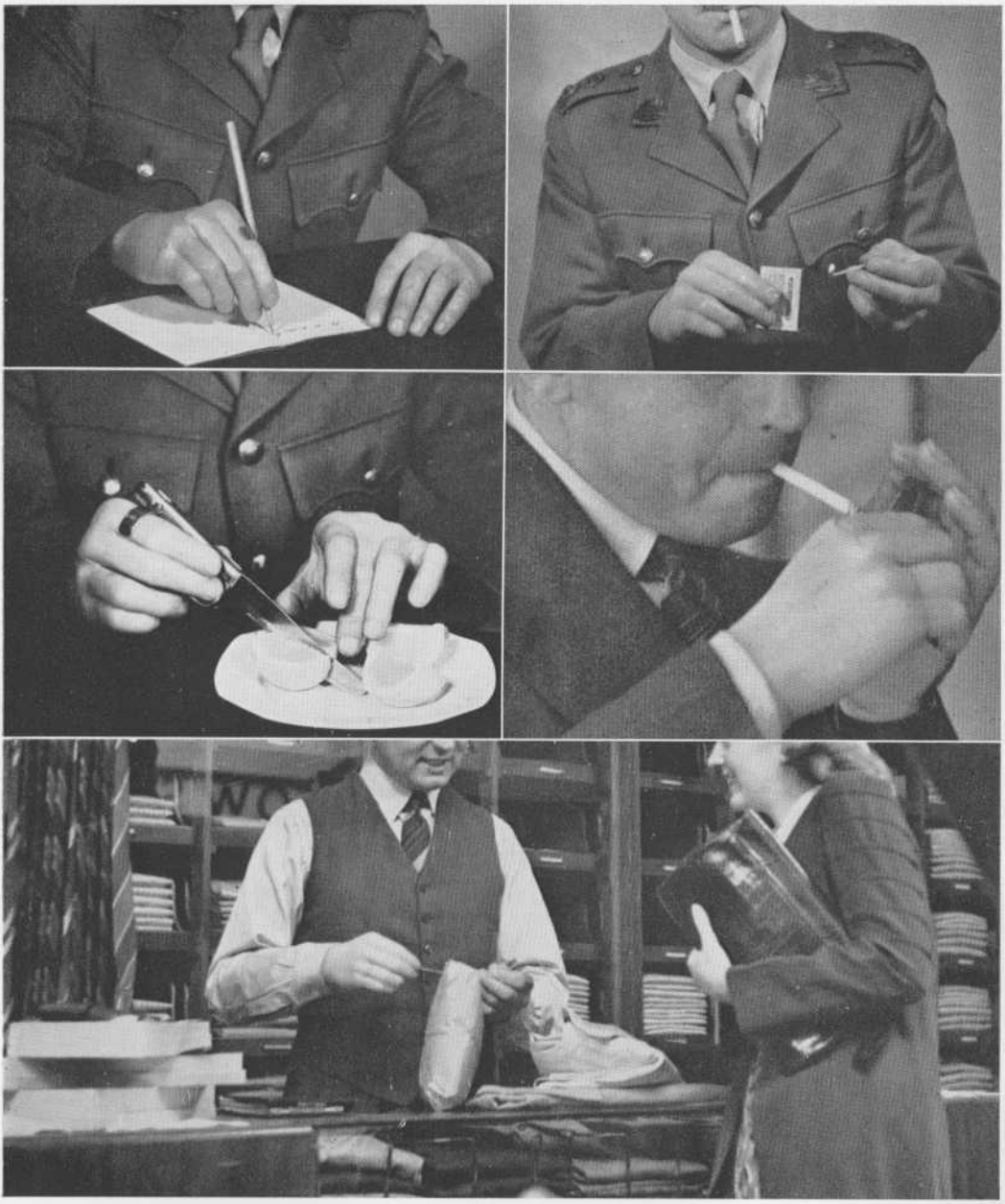
(B. K. Rank)











(B. K. Rank)

Manipulations with cine-plastic hand.

opened in January 1941. The dusty winds of summer had established a tradition, that operative work could not be safely carried out there during the hot months, but experience proved this to be incorrect.

During this year, no less than 486 men were seen at this hospital with a tentative diagnosis of internal derangement of the knee joint, this large number being accounted for by injuries received while playing football, by falling into slit trenches at night or in transport accidents. These men belonged to a number of categories, some having mild infections, some minor mechanical derangements and other symptoms justifying arthrotomy. Of the last class the most common symptom was insecurity or "giving way" of the joint. Locking was only unequivocally described in forty-two instances. The chief surgical difficulty in this series was not diagnosis but after-treatment, as the only possible choices of environment were hospital, convalescent depot and the man's unit. Except for some mild skin sepsis at first careful technique of preparation and operation secured direct healing. The early troubles were eliminated by using interrupted sutures of silk instead of gut and using an anchored dressing for three days only instead of a bandage. Immediate active movement was begun, and the results ran parallel with the readiness with which the patients cooperated in exercising the quadriceps muscles and moving the limb. Walking was encouraged after a few days; splints and crutches were not allowed. Only two effusions needed aspiration. Further treatment was found better carried out in hospital than in a convalescent depot, and the men were kept in tents in the hospital area where they could receive attention and be given graded exercise until they could be discharged to a depot battalion in an average of forty-two days. Of 128 men, 104 were regarded as fit for active service, and 15 others fit for service other than with field formations.

Later experience of soldiers thus treated suggested that the number originally found fit decreased gradually. A few of these had effusions into the joint after resuming full work. These usually disappeared on treatment, but other observations have shown that a proportion of the patients (32 out of 119 of Duthie and MacLeod's series) had to be down-graded later. Recurrent or persistent effusion, a complication known to occur, has not been absent from military series.

Graham's series is of interest as it embodies the results of operative work done at an oversea base. A higher percentage of successes was recorded by Hembrow and others in the Royal Australian Air Force. This is no doubt due to the different type of work done in this Service, in which large numbers of men belong either to air crews or to skilled trade groups. Of a series of 200 men on whom the operation of meniscectomy was performed between 1942 and 1945, 140 were followed up. Eighteen (12 per cent) of the men complained later of trouble with the knee; of these seven were permanently unfit, four lowered in category and the rest returned to full duty. These observers had the impression that the injury was more common than in civil life: it was produced by strains of widely differing intensity, but the commonest cause was twisting the semiflexed knee. At first operation was undertaken only after recurrence of the primary symp-

toms, but later it was performed once a confident diagnosis was made. Absence of a history of trauma suggested *osteochrondritis dissecans*. It was thought justifiable to operate even if some slight degree of arthritis was present if the man's usefulness might be expected to be improved, but of thirteen men so treated nearly half were unfit later. The average time off duty after operation was forty-seven days.

The importance of after care in these operations is illustrated in the Army Technical Instruction No. 20, in which it was laid down that in all interval operations involving opening the knee joint the surgeon should retain the men under his personal care till they had

(a) no effusion in or thickening round the joint,
(b) had regained reasonable recovery of the quadriceps,
(c) had full range of movement in the joint.

After six months duty as a B class soldier the man was reassessed for fitness by a Medical Board.

PRINCIPLES OF TREATMENT OF FRACTURES

The treatment of fractures in the field has been covered in part in sections dealing with wounds of the extremities. These sections have in the main referred to compound fractures, that is, wounds of the limbs associated with fractures of bones. Some amplification is necessary of the functional aspects of treatment of these and other injuries which disrupt the structure and function of the bones and joints. The general coordination of the principles involved was the care of the Director of Surgery under the D.G.M.S.; this need not be discussed here except to refer to one or two problems. Attempts were made in Middle East to concentrate orthopaedic types of injury or battle casualty in one centre at Kantara, the 2/2nd Australian General Hospital, and later in Australia an orthopaedic hospital was established at Toowoomba. Difficulties of transport were obvious in the first instance and still more so in the second. The same problem arose when it was planned to concentrate long term orthopaedic patients at Asmara in Eritrea. That there were advantages in centralisation was evident in some ways; coordination and more or less standardisation of methods and aggregation of numbers of patients with similar disabilities helped to train medical and nursing personnel, and techniques for rehabilitation could be evolved on a large scale. The reverse plan of admitting orthopaedic casualties to a number of surgical wards of a general hospital was briefly tried, but though it diffused a special type of experience among a greater number of surgeons, it was not a success either for staff or for patients. Probably, having regard to the distances and conditions of transport in Australia during the years of the Pacific war, it was best to have an orthopaedic department as part of the organisation of the surgical division of a general hospital, with an orthopaedic specialist, and trained physiotherapists and occupational therapists. There is no doubt that orthopaedic departments and hospitals help greatly in raising and maintaining the standards of surgery, after care and rehabilitation in this specialty.

Though there was never any suggestion of so standardising treatment to a point where individual judgment of surgeons was hampered, the value of standard procedures was undoubted. For example Keon Cohen's series of thirty-two cases of fractured femur quoted in the section of wounds of the lower extremity, illustrates a statement of general functional principles and a selected procedure. The principles involved were as follows: (a) a fracture must be reduced and the corrected position maintained under radiological control, (b) immobilisation must be complete and continuous till sound healing is attained, (c) all parts save those immobilised should be actively exercised to maintain function of muscles and joints. In all these matters the goal to be kept in mind is complete rehabilitation. Where a long voyage was faced by the patient before he reached his home base, not only his immediate comfort had to be studied, but the degree of functional activity it was hoped he would attain. These principles of course applied also to fractures of less risk and difficulty of handling than the fractured femur.

The actual ward routines adopted in the series were as follows: (a) the limb was slung in a bent Thomas splint, (b) skeletal traction was applied through the tibial crest, Steinmann pins being found more reliable than Kirschner wire, due in part at least to difficulty in obtaining wire of requisite quality, (c) reduction was affected in the first place under general anaesthesia, (d) position and alignment were periodically checked by portable X-ray machines, and (e) patients repatriated from Middle East to Australia had a plaster spica applied, and with a view to future function the knee joint was not immobilised in full extension.

In Australia it was found that after patients under treatment for injuries and joints had passed the hospital stage, they presented some problems in various rehabilitation centres such as convalescent depots and homes and rehabilitation units, the last mentioned being the more stimulating term used by the air force. Many of the patients in these institutions were long term patients with orthopaedic disabilities. During the latter stages of their hospital treatment the problems of handling were simply solved, as these patients were usually in a hospital with a well equipped and staffed physiotherapeutic department. Certain hospitals, without being solely orthopaedic hospitals, concentrated on surgical patients of this kind. Physiotherapy steadily progressed during the war, being nurtured by orthopaedic surgeons from the beginning, and developed by their enthusiasm and that of the fully trained and experienced physiotherapists. Even the dropping of the term "massage department" was a distinct gain, as it unfairly implied a degree of limitation of scope and methods.

For some time before the end of the war the Repatriation Department did not have facilities for rehabilitation of patients with orthopaedic disabilities comparable with those available in the armed forces. Squadron Leader G. G. Burniston voiced the needs of these patients in a report to the D.G.M.S., R.A.A.F., and pointed out that at this stage while special repatriation and Red Cross institutions provided for men with tuberculosis or neuroses, similar advantages were not freely available for the ortho-

paedic patients. Therefore it was desirable that existing facilities should be used either before or after the men in question appeared before final medical boards. If such appearances were delayed it would be possible in many instances to reduce a "total" permanent disability to a partial one. Though this is more a matter of administration, a very important clinical question is involved, as the time in months occupied in restoring maximal function to these patients was a small matter compared with the future years in which handicaps might become more obvious instead of less.

Fracture of the navicular bone in the wrist deserves special mention as it often caused disability over a considerable period. Usually caused by falling, it was not uncommon, especially when suspected by medical officers. One area in Australia reported that it was more common than fractures of the clavicle and Colles fractures. The difficulty familiar in securing union of this bone, the need for radiological diagnosis and the necessity for continuous immobilisation were stressed in technical instructions (Nos. 38 and 3 respectively) issued by the medical services of the army and the navy. Even if these fractures were unrecognised for a considerable time, immobilisation was usually successful, but non-union called for advice and action of an orthopaedic specialist.

The standard method of treatment for this fracture was immobilisation of the hand in plaster in the "tumbler" position, with the wrist extended 15 degrees radially abducted 10 degrees and the thumb in line with the flexion action of the index finger. The plaster, including the first phalanx of the thumb, was maintained usually for three or four months. Only slight disability was found later as a rule, but occasionally it was severe and was then sometimes associated with arthritic change. Excision was sometimes necessary.

LESIONS OF THE INTERVERTEBRAL DISC

The importance of lesions of the intervertebral disc in the causation of sciatic pain was reflected in the surgical experiences at base hospitals. Though included here in an account of orthopaedic work, the conditions caused by these lesions may with equal justice be regarded in the province of the neurosurgeon. In the Services, however, most patients came under the review of orthopaedists. It is not possible to say in what proportion of soldiers with sciatic pain disc lesions were the cause. Sometimes the diagnosis was made but not proved by operation, since the symptoms were relieved by immobilisation. A representative series has been reported by Douglas Miller and G. Vanderfield. During a period of twelve months 107 patients were treated in the Neurological Centre at the 113th (Concord) Military Hospital in Sydney. Most of them had already had conservative treatment of different kinds. Of these men 53 were submitted to operation. Only 19 had a history of injury. The average length of symptoms was nineteen months, but there were wide variations. The pain was frequently aggravated by exertion, coughing or sneezing. Restriction of movement was also frequent, so too was scoliosis to the opposite side. Muscle spasm

was almost always demonstrable by appropriate tests. Considerable importance was attached to the ankle jerks: alteration of this reflex usually was associated with a lesion beneath the first sacral or fifth lumbar nerve. Areas of reflection of pain were often helpful in localisation. Relief of pain by immobilisation was found of great diagnostic value. Conservative treatment was used for those patients whose symptoms were mild, and in these a short leg spica was tried for one month. At operation interlaminar exploration was carried out first at the predicted site, usually without removal of bone. Part of a lamina was removed, if necessary, for exposure, and degenerate material was removed as usual. Of forty-six patients with protruded disc, thirty-seven obtained dramatic relief. Recurrences were encountered in three patients, one at the orginal site, and two on the opposite side. It is interesting that the best results were obtained in those patients whose pain was most severe.

APPENDIX

Technical Instruction No. 25

Disabilities of the Feet—Indications for Treatment

Before arriving at a decision due regard must be paid to the *age* of the soldier, general health, tendency to put on weight, and to any other disabilities that may render physical interference valueless, e.g., a knock-knee.

Operations will not be carried out in hospitals of less than 600 beds. After operation soldiers will not be discharged to convalescent depots, etc. They will remain the personal responsibility of the operating surgeon until they are fit to rejoin their unit or base details.

At operation *corrective* measures will be used as far as possible; *toes will not* be amputated.

Soldiers who have severe degrees of disabilities of the feet, e.g., *hallux valgus* and *pes cavus*, will *not* be operated on.

A soldier suffering from a disability of the feet whom, on examination, the surgeon considers to be in too high a category because of that disability, and unable to carry on in the Army in that category, *will not* be operated on unless the original category can thereby be stabilised or improved.

The only *exception* to the above generalisation will be for the relief of pain that is disabling.

The operative treatment indicated for the more common disabilities are as follows:

Bunion.—If there is no arthritis in the metatarso-phalangeal joint and if deviation of the great toe is not severe, symptoms may be due solely to pressure on the exostosis.

Removal of the exostosis may in such cases give complete relief of symptoms and will allow the soldier to wear with comfort army boots.

A skin flap should be turned down so that the scar will not be subject to pressure.

It will be found quite often that when the exostosis is removed the joint is opened. This is unavoidable and does not give rise to any ill-effects.

Hallux Valgus.—Few cases of *Hallux Valgus* will justify—in the army sense—surgical interference. In those cases in which the disability is real and sufficiently pronounced to raise the question of radical operative interference, the advisability of lowering the category and carrying on with more conservative measures will be considered.

Hallux Rigidus.—The same applies to this condition as to *Hallux Valgus.*

Hammer Toe.—The common hammer toe of the 2nd digit can be *readily cured* by excision of the proximal phalanx. Alternatively the proximal inter-phalangeal

joint may be arthrodesed, but care must be taken to overcome dorsal flexion of the proximal phalanx.

Pes Cavus.—Few cases will justify interference. Where disability is due mainly to corns or clawed toes, appropriate treatment for the corns will often be satisfactory.

Ingrowing Toe Nail.—The "wedge operation" carefully performed so that "needles" are not left is satisfactory.

In those cases, onychogryphosis, etc., in which removal of the whole of the nail and nail bed is necessary, a small portion of the terminal phalanx must also be removed in order to allow the plantar flap to swing into place.

Fifth Metatarsal Bunion.—This is neither as common nor as troublesome as the bunion over the head of the 1st metatarsal bone. If it is *disabling* and *is the only disability* present, satisfactory results are obtained from an analogous operation to that performed for the more common variety on the inner side of the foot.

Plantar Papillomata.—Most of these can be cured by careful curetting under local anaesthesia. The resulting hole is packed with gauze soaked with 2½ per cent iodine for 5 minutes. Tinct. Benzoin Co. dressing is applied.

No hospitalisation is necessary.

Painful Heel.—Surgery is *not* indicated. Padding with sponge rubber, if available, for the plantar portion of the heel or with felt for a painful tuberosity is satisfactory.

Metatarsalgia.—Operative intervention *will not* be carried out for this condition.

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CHAPTER 41

AMPUTATIONS

FORTUNATELY the number of servicemen requiring amputation of a limb has not been as great in the 1939-1945 as in the 1914-1918 war. The total of 682 among 39,803 Australians wounded in the 1939-1945 falls far below that of 3,241 in the previous war. Surgically this problem becomes significant from the moment of first aid, and continues so during the life of the limbless man. It will be understood that the word "limbless" is used in the sense of "having suffered an injury resulting in the loss of at least part of one limb".

An early technical instruction (No. 22 Middle East) dealt with the handling of men whose injury required amputation. The argument about "guillotine" amputations raised during the 1914-1918 war was renewed among surgeons, but the instruction pointed out that the term guillotine was sometimes interpreted too literally. Amputation performed as to make a straight cross section of a limb was of course usually indefensible. However, in operations done under conditions of war flaps should never contain muscle, on account of the risk of gas gangrene or spreading sepsis, and sometimes it is also necessary to cut straight across the muscular planes at the site of section of the bone. Flaps were left unsutured, but loose coaptation by a few sutures was permitted. Sometimes a few stitches were used to hold flaps back from the stump. The importance of drainage of this primary operation was enhanced by an understanding of the serious sequels possible from an undrained haematoma. The instruction further pointed out that while sites of amputations were in accordance with the usually accepted principles, sentiment should never obscure judgment. Of course conditions made a difference in the choice of the site. It is quite a different matter to amputate a limb obviously too shattered to warrant any attempt at salvage, and to be forced to undertake amputation after unsuccessful treatment of a compound fracture or a suppurative arthritis. In some instances of the latter in the thigh the site would perforce be at a high level, but this operation was often not formidable, as the existence of muscle wasting simplified procedures and blood transfusion before and after largely prevented shock. Such decisions were often difficult to make, even in base hospitals where the whole procedure was deliberate; in forward areas surgeons were particularly warned of their responsibility to patients on whom immediate amputation was necessary, and instructions stressed the importance of drainage and other measures designed to lessen the risk of infection. Conservatism was also important, in regard to the man's future. In war surgery the indications for amputation are severe damage to a limb, in particular where important blood vessels and nerves are seriously injured, and where complications of further vascular accidents and infection may endanger life. The operation is then designed to leave as much useful tissue as is wisely possible. As will be seen later,

the changes wrought by chemotherapy have introduced another factor for consideration. It is not necessary here to give details of methods appropriate to each site. In general it may be noted that the problems raised by injuries of the upper limbs are less serious than those of the lower limbs. In the upper limb infection does not tend to spread upwards so readily, and can be more easily controlled, but drastic measures were sometimes necessary to avert blood infections. The fate of a hand was not always easy to decide, owing to its functional importance, but once its loss was inevitable the site of amputation was not so difficult or significant. The peculiar problems of the wounded hand are discussed in detail in a special section.

Once safety from bleeding or infection has been assured the problem of the limbless man's future must be foremost in consideration. The performance of amputation of a limb must of course be done with the goal of the maximum functional activity of the limb before the surgeon's eyes. In the past re-amputation or at least some surgical re-adaptation of the stump for functional purposes was common. In fact in the 1914-1918 war a long stump was usually left to ensure that enough tissue was available to enable an ideal stump to be prepared later for a prosthesis, but sulphonamides and penicillin have made many primary operations definitive. Thus the limb-fitting surgeon can no longer centre the prosthesis round the ideal stump, he now often has to devise and fit prostheses for stumps which, though functionally practical, he would once have classed as not ideal.

Of course this only sharpened the interest and technical skill of those who since the war of 1914-1918 had been concerned with caring for limbless men, and the introduction of new alloys and methods of design and construction helped further advances. A lecture by Dr R. D. Langdale Kelham, Chief Limb Fitting Surgeon to the Ministry of Pensions, England, was circulated *in extenso* to all medical officers in the army medical services as a technical instruction. This was informative and stated the current views in England. Technical Instruction No. 88 was later issued which may be taken as expressing the general views of the Australian Army Medical Services (see appendix).

In the later years of the war a difficulty presented itself in regard to limb fitting. This was that in Australia there was a dearth of young surgeons who had special experience in this branch of orthopaedic surgery. Need was felt for a rejuvenation of limb manufacture in Australia. Difficulties were considerable in making cineplastic prostheses, which had not kept pace with the surgical developments. At this time Air Vice-Marshal Hurley arranged for a mechanic from the R.A.A.F. to work in the laboratory dealing with prostheses. The step was taken of sending a special delegation in orthopaedics who could report to the medical heads of the armed Services and the Repatriation Commission on the work being done abroad and the requirements in Australia. This delegation consisted of F. H. McC. Callow, B. T. Keon Cohen and J. M. Jens, who presented a report and later published an account which summarised the indications for various types of amputations.

Investigation overseas showed that agreement was by no means universal about the value of certain types of amputation and of the stumps they produced. The wider outlook of recent work, as remarked above, has extended the field in various ways, and future experience alone can solve some of the problems.

Here it is sufficient to state some general and non-controversial principles. In carrying out an amputation the total length of the flaps was taken as at least the diameter of the limb, the muscles were divided at the point of bone section sufficient fascia being preserved to cover the bone. No special treatment was given to nerves other than cutting them after gentle traction. Drainage of the stump was advised for a day or two to obviate haematoma. A technical instruction (No. 44) on the care of amputation stumps directed that a full range of movements in all directions should be maintained in the joint or joints above the site of amputation, and that such pressure should be applied to the stump as could be obtained by the firm application of a crepe bandage. The need for special precautions during the patient's transit to a base hospital was recognised. Therefore, while the preservation of joint mobility was necessary, it was also advisable to ensure that retraction of the tissues on the stump did not occur. To this end traction in a Thomas splint with stockinette and skin glue was advisable.

After penicillin had been made freely available, secondary closure was often safely possible at an early stage after the wounding of the patient. If this could not be done and if re-amputation was necessary, this was carried out at a stage when in the judgment of the surgeon the wound was healthy enough to justify action. Here again penicillin afforded a great measure of security in the control of sepsis.

The fitting of a prosthesis was made simpler and good function was more likely if adequate preparation had been carried out. Physiotherapy and exercise were essential at this stage. In some instances a temporary pylon was fitted to bring about correct shaping of the stump.

If re-amputation was necessary this could be done without waiting for complete healing, and the general feeling was that a general assessment of the patient's general and local conditions was more valuable than the findings from bacteriological culture. Callow, Keon Cohen and Jens stated the local criteria as follows: firm granulation of the surface of the wound, including the sectioned bone; absence of sloughs; minimal discharge; absence of oedema; no radiological evidence of sequestra or bone infection; and a healthy ingrowing skin margin. Skin grafting as a temporary measure was sometimes necessary; if permanent augmentation of skin in the weight-bearing area was required it was necessary to use pedicle grafts of full skin thickness. In these final readjustments penicillin lessened the risk of sepsis and accelerated the whole procedure. Ideally the stump when ready for a prosthesis should then be firm and free from oedema, with the remaining musculature of good function, and there should be no deformity or stiffness of joints. Complications of amputation stumps are important, as even minor disturbances may make the wearing of a

limb impossible. Very little trouble was encountered with the earlier complications, such as spasmodic muscle twitching or pain in a phantom limb. The later complications such as tenderness of the scar, boils or sebaceous cysts belong to the period of after care, but one of these is important from the preventive aspect. This is the formation of an annular roll of tissue over the origin of the adductor muscles of the thigh after amputations above the knee. The full solution of this and other problems relating to the fitting of prostheses to some of the more troublesome types of stump is still receiving close attention from all official organisations dealing with "veterans" of all countries. The British Official Medical History of the war should be consulted for recent work on the subject.

The extension of the principles of plastic surgery to the preparation of amputation stumps for prostheses has introduced a somewhat new aspect of the subject. By the use of the familiar plastic procedures it is possible not only to save time eventually, but also to provide a better weight-bearing area. Therefore the collaboration of the plastic surgeon in this branch of orthopaedic surgery, or at least the adoption of the principles of his work, has conferred definite benefits. These principles were chiefly applied as follows.

Unsatisfactory scars or chronic wounds in relation to weight bearing areas were replaced by flaps of skin and fat, either as cross leg flaps or as migration pedicles from the trunk. Useful joints such as the knee could thus be sometimes retained.

Palliative grafts have been used freely on wounds near amputation stumps so as to promote healing and hasten future reconstruction. Such efforts were of particular value in assuring healing before section of bone in re-amputation was attempted. In the pre-penicillin era breakdowns in these cases were a frequent source of disappointment.

Cineplastic re-amputations were carried out in 2nd Plastic Unit at Heidelberg on a small series, advantage being taken of the collaboration and facilities there. The results were very gratifying particularly in relation to hand prostheses of this type, and were reported by B. K. Rank and G. D. Henderson.

The commission investigating the methods of treating limbless men found some divergence of opinion in England and the North American Continent about the value of various sites for final amputation. In general the mid-tarsal amputation of the fore-foot was not approved as it created an *equino-varus* deformity. Other modifications of this were under trial. The Syme amputation was one of the most controversial. In England more than half the men with this amputation resulting from war wounds in 1914 have had re-amputations, and only 20 per cent of the remainder were able to tolerate full weight-bearing on the end of the stump. In Canada experience was different, and re-amputation was unusual. In the United States also there was confidence in this operation which was still being performed. Examination of men with a long history of Syme's amputation showed, however, that deterioration was not unlikely. Various reasons are given for this, some due to faults in the technique of fashioning

the flaps, or to later defects in blood supply, others due to faults in the prosthesis. There seems no doubt that this operation calls for great precision, following the original description of Syme, for close post-operative care and the provision of a light prosthesis whose attachments do not constrict the blood supply.

In the leg, stumps not longer than 5 or 6 inches were preferred, and in the thigh, stumps not longer than 10 inches. Here too, and also in the fitting of a limb after disarticulation of the knee joint it seemed as if the last word had not been spoken. Though the longer stumps have given trouble, they are not alone in this, and recent work in Canada and U.S.A. indicates that satisfactory results may be attained in circumstances once thought unfavourable. As pointed out before, the long stump may be more frequently seen owing to the possibility of securing earlier healing without much risk of sepsis. The ideal length of the stump in mid-thigh amputation is stated at ten to twelve inches of femur from the tip of the great trochanter.

In the upper limb functional considerations are different. Consideration of the hand is paramount. This is dealt with elsewhere. Vascular deterioration may occur in upper limb stumps also. Disarticulation at the wrist joint has been associated with vascular and mechanical troubles, but improvement and lightening of the appliances may yet preserve its value. In forearm stumps the same may occur, but here too it is possible that the objections to stumps longer than the "ideal" 7 inches from the tip of the olecranon may be overcome by lighter and better prostheses. The value of the unaided arm stump must always be remembered with the great advantage of direct skin sensation. Amputation through the upper arm usually needs 4 to 8 inches of humerus from the acromion. The Krukenberg claw forearm, with certain advantages of application of direct muscular force and of useful sensation has not been used in the Australian forces. Cineplastic operations have been mentioned, but cannot be dealt with here. They require a cooperative intelligent patient, capable of a high degree of muscular training, a close alliance of orthopaedic and plastic surgeons, and a great expenditure of specialised knowledge and technical skill in constructing a practical prosthesis. The future will surely see many improvements in prosthetic appliances. Material and mechanical devices are now more varied and applicable to a wider range of disability. Moreover the peculiar problems will receive fresh consideration, and cortical cerebral function should be able to be expressed better through mechanical means.

This history does not follow through into the post-war period, and hence is not concerned with the activities of the Australian Repatriation Commission. Though the after care of men who have suffered amputation of a limb naturally concerns the Repatriation medical service, the fitting of prostheses and rehabilitation of these men concerned also the medical services of the army, navy and air force as an important part of their responsibility while they had full charge of the large base hospitals. The necessary training to prepare men to face the world after amputation began

in the base hospitals once the stump was firmly healed with a painless scar and could be handled without discomfort, and when the most rapid degree of shrinkage was over.

LEG TRAINING

The first important point in training was to ensure that the prosthesis was worn for only short periods during the first few days, to avoid possible damage to the stump. The art of balance and of walking then were taught, two sticks being allowed first and later dispensed with. Walking along lines and in front of mirrors as practised in oversea centres has been found of great value. Later patients were trained to walk over obstacles, to negotiate stairs and to mount vehicles with confidence.

ARM TRAINING

This is of great importance, as a man lacking an upper limb is much more likely to use a prosthesis to full advantage if his training begins early, so that he may be helped over the most difficult stages. Effort was directed towards encouraging the man to use both arms. Where classes could be organised for special instruction in every day activities, especially those of domestic and industrial nature, progress was more rapid and satisfactory. Some effort was made at Heidelberg and Concord Military Hospitals to construct and use "panels" of all varieties of domestic fittings and public utilities.

Ideally close cooperation should be maintained between the designers and makers of prostheses, and the surgeons responsible for the preparation of a suitable stump. Thought has also to be given to the probable future activities of the patient, so that he may early acquire confidence and cooperate in learning new muscular adjustments necessary and the applications of his prosthesis if he can be fitted with one, to everyday life.

Economic training is of the first importance. It is beyond our present scope, but it is obvious that from the first surgical steps taken to repair the damage of war thought must be given to the fitting of each man in an altered state into a community of people who cannot fully understand his difficulties. That a wider range of occupation is opening out before men who have lost a limb is a challenge not only to the medical profession but the whole of society.

AMPUTATIONS IN JAPANESE PRISON CAMP HOSPITALS

Amputations were unfortunately necessary to relieve the inescapable sufferings of men with severe so-called "tropical" ulcers of the legs in the various Japanese-controlled working camps and associated hospitals. The subject of tropical ulcers is dealt with in the section on medicine and surgery in captivity, from the clinical aspect, and the fuller story of the Australian medical officers' work in these hospitals will be told more adequately in the operational volume dealing with the South-East Asian Area. Here only a brief reference can be made to the methods

adopted. Amputation was a risky procedure on these debilitated men, faced with daily hazards of cruelty, malnutrition and tropical disease. Spinal anaesthetics were usually employed.

Captain F. J. Cahill, A.A.M.C., in reporting a series of 420 men suffering from tropical ulcers in Tanbaya camp hospital, described the almost incredibly unfavourable circumstances under which amputation became necessary for the rapid spreading of these ulcers. The tibia was often exposed and wide-spread sepsis was very common. Amputation was done on 40 men, at first as low a site as seemed advisable being chosen, but the site of election too often ran through an ulcerated area, and sloughing of flaps was frequent, often with secondary haemorrhage. Cahill found the association of oedematous beriberi with acute ulcer was very often fatal, and in this condition amputation was abandoned. The level of amputation was at mid-thigh in twenty-five cases and the upper third of the thigh in fourteen. Though these men survived immediate operation, only four patients were still alive three months after the last operation. Under more favourable conditions the hazard of spreading sepsis and chronic osteomyelitis in the lower limb could be reduced by an earlier and bolder policy of amputation at a reasonably high level before ulceration spread in the limb. At the stationary hospital finally reached at Nakom Paton Lieut-Colonel A. E. Coates and his colleagues found that by mid-thigh amputation they could avoid the danger of sepsis invading the fascial planes, and could even coapt the flaps to aim at primary healing. It was remarkable that this could be attained in a high proportion of cases. Even so, of 173 men who recovered from amputation at Nakom Paton, half the number, despite satisfactory healing, died at variable periods afterwards from intercurrent disease of infective or nutritional origin. Experiences in several of the camp hospitals in Burma and Thailand showed that conservatism was often dangerous. The most favourable site for amputation was the mid-thigh: the upper third of the thigh was less suitable, owing to the risks of sepsis and secondary bleeding.

In a different category were German surgeons in some of the German prisoner-of-war camps, who were distinctly more radical in outlook than British or Australian surgeons. For various traumatic conditions they advised amputation of a limb in patients who later made a good recovery under conservative treatment by their own medical officers.

APPENDIX

Technical Instruction No. 88

Amputations

Where to amputate—

The teaching now is to leave the shortest stump that will efficiently control the artificial limb.

The passage of time has shown that circulatory disturbances and ulceration occur in the end of long stumps. Long stumps may furthermore prevent the patient being fitted with the most serviceable type of limb. This is noticeably so in long leg stumps in women. The prosthesis available for these is unsightly.

Site of election are—

In the lower extremity:

1. One inch above the ankle joint; the Syme amputation. This is satisfactory only if it is performed using a short non-bulky flap.
2. Five and a half inches, not 4 inches, below the line of the knee joint. A stump shorter than 5½ inches can be fitted with an artificial limb, stumps as short as 3 inches should be preserved.
3. Ten to 12 inches measured from the top of the great trochanter. There must be at least 6 inches of femur for the fitting of an artificial limb.
4. Four inches of femur, measured from the top of the great trochanter, is ideal when only a tilting table limb can be fitted.

In the upper extremity:

1. Seven inches below the tip of the olecranon.
2. Eight inches below the tip of the acromion process. An amputation immediately below the shoulder joint or hip joint is to be preferred to a disarticulation.

It must be insisted that as a primary operation in the forward area the maximum length of limb possible will be preserved. In these circumstances operation will not be carried out at the site of election. The consequences of failure of asepsis resulting in a limb too short for the most suitable prosthesis are too serious for this risk to be undertaken.

Skin Flaps—The aim is a linear scar, free from folds, away from pressure and freely mobile.

A linear scar implies freedom from infection, this irrespective of whether the suturing is carried out as a primary delayed or secondary procedure. A scar without puckers implies that the skin edges must be of equal length. This is easy to achieve if the flaps are of equal length. It is, however, not so simple if they are of unequal length, the common procedure to effect a posterior scar, then the posterior flap should encroach on the anterior half of the circumference. The skin incisions should be tapered, not rectangular as in operative surgery demonstrations. A coronal wound heals better than a sagittal. The old fashioned operation of equal lateral flaps will not be carried out unless the skin loss prevents antero-posterior flaps.

A mobile scar is obtained by the avoidance of haematoma formation or infection. In the lower extremity a scar that is a little posterior is to be preferred. The flaps consist of skin and subcutaneous tissue only, the muscle is cut circular fashion at the point of section of the bone. The bone is divided at right angles to the shaft. The periosteum is not disturbed prior to or after section of the bone.

In the leg the sharp anterior edge of the tibia is removed and the fibula cut across one to one and a half inches higher than the tibia.

The nerves should be cut cleanly at a slightly higher level than the muscles but should not be roughly pulled down to do so. They should neither be crushed nor ligatured unless to control haemorrhage. The end of the bone is covered with *skin and subcutaneous tissue* only.

Formerly when stumps were end-bearing the aim was to prevent a conical stump, stumps are no longer end-bearing and a conical stump is to be desired.

Whether the flaps will be sutured immediately or as a delayed primary or secondary procedure will be determined by:

(a) The condition for which the amputation was performed.
(b) The time that had elapsed between the injury or onset of the pathological condition.
(c) The condition of the tissues as revealed at operation.

If this technique is carried out in forward areas the risk of gas infection spreading in the muscle is to some degree obviated as the muscle has been excised to the level of the line of section of the bone. A few coapting sutures can be used at any period of from 36 hours to a few days.

In forward areas flaps will not be sutured at the time of the original operation.

Amputation through the knee joint, as a temporary expedient in cases of irreparable injury below the knee or intractable septic arthritis has a definite value. Because

of the few structures interfered with amputation through the knee joint is associated with less haemorrhage and shock and is more quickly carried out than any other amputation through the leg or thigh.

Injury about the wrist—If an amputation is inevitable nothing is gained by saving the inferior radio-ulnar joint. The attachment of a prosthesis to a stump in which the inferior radio-ulnar joint has been retained presents difficulties of such a nature that normal pronation and supination combined with a useful mechanical hand cannot be obtained.

Guillotine amputations—The modern amputation is in fact guillotine except for the skin and subcutaneous tissue flaps.

The protection to the large raw area provided by skin flaps, even when such are not sutured, is so beneficial that flaps should be cut wherever possible. There will be few cases where this procedure will not be possible either because of the extent of the injury or the operating time involved.

Guillotine amputation *will not* be a routine procedure and will *only* be carried out in cases of extreme urgency.

Whenever a guillotine amputation is performed or skin flaps are unavoidably short because of the injury to the soft parts skin traction will be applied to prevent retraction.

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CHAPTER 42

HEAD INJURIES

IN January 1941 Colonel Hailes, the Consulting Surgeon of the A.I.F. in the Middle East, issued instructions concerning the treatment of head injuries in the field. These were based on a memorandum drawn up at his request by Lieut-Colonel Lindon, in charge of the surgical division of the 2/2nd Australian General Hospital. He recommended that advanced surgical teams should deal only with the scalp and bone, leaving further measures to be carried out at the farthest forward hospital with adequate equipment and a trained neurosurgical staff. Unless there was excessive bleeding patients were allowed to recover from shock, and further interference was deferred for another twelve to twenty-four hours.

The advanced team was advised to cleanse the whole scalp, excise a thin layer of devitalised skin, and remove any loose fragments of foreign bodies. The dura was not opened unless penetrated, and if penetrated only superficial treatment was then necessary. Bleeding should be stopped and primary closure of the scalp attempted, at least by a flap of scalp in order to cover the bone defect if possible. Major exploration was best deferred for some days, provided the initial cleansing had been done thoroughly. Then the track of the missile could be dealt with and foreign bodies removed. The severer lesions with gross neural damage and contamination would be likely in any case to do badly as regards function.

Early in 1941 Colonel Hailes summarised the treatment of head injuries as follows:—

"1. The extent of comminution of the bone and the depth that the bone fragments are driven into the brain is remarkable, especially when, in many instances, careful radiological examination reveals the absence of any penetrating metallic foreign body—these missiles have been either tangential or non-penetrating.

2. The removal of these bone fragments is a formidable proceeding, quite outside the scope of cerebral surgery in a forward area.

3. The resistance of cerebral tissue to infection is considerable; if the scalp wound is cleaned and dirty tissue excised, obvious depression bone removed, edges cleaned and excised, pulped brain gently irrigated, and the scalp sutured, that is all that is necessary in forward areas. Sulphonamide is given in the recognised doses.

It has been shown that efforts to do more in forward areas only cause unnecessary damage, and that with the treatment indicated above the cerebral tissue reacts well to infection; and that the drainage of abscesses and removal of indriven bone and retained metallic F.B.'s is a surgical procedure much better carried out at a Base Hospital than in the bustle of a forward operating centre.

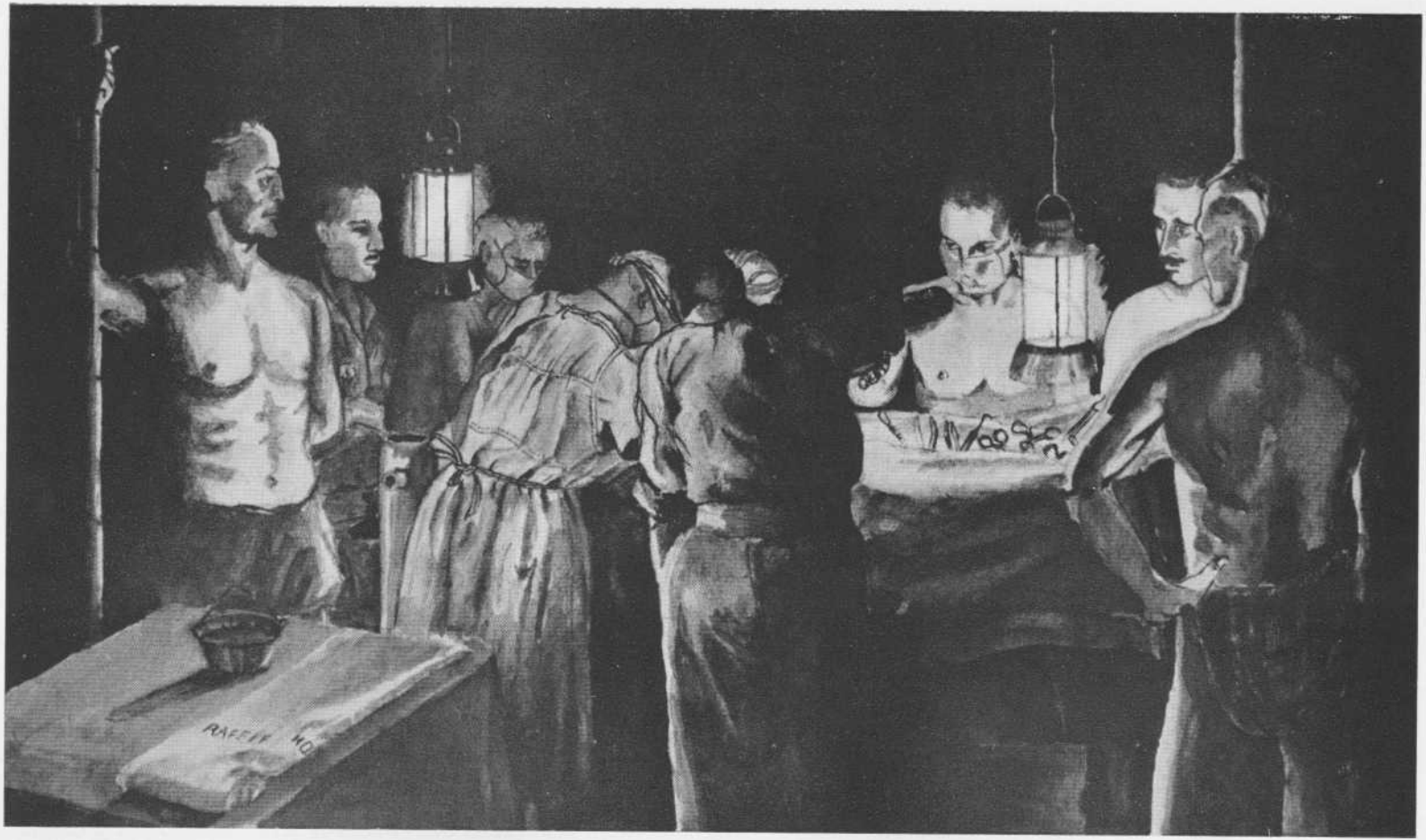
The treatment indicated at the forward operating centre can be performed satisfactorily by general surgeons. The cranial surgeon, who is essential to deal satisfactorily with the cases of cerebral abscess, cerebritis and retained foreign bodies, should be stationed and work in the relative quietness of an accessible, well equipped base hospital.

We have no intention of sending any other than young general surgeons to forward centres and will keep these special centres in base hospitals. This applies to neurosurgical, thoracic and orthopaedic and plastic units."



(Australian War Memorial)

Improvised back rest for patient after operation for abdominal wound—New Guinea.



(Drawn by P. Meninsky)

Night operation for perforated duodenal ulcer, Tamuang.

DEVELOPMENT OF METHODS

In the first Libyan campaign there were few head injuries and they were not concentrated in any particular centre. The same held good for the campaigns in Greece and Syria.

In the middle of 1941 the 2/2nd A.G.H. at Kantara was constituted as the neurosurgical centre, the work being under the care of Lieut-Colonel L. C. Lindon: when the 6th and 7th Divisions A.I.F. returned to Australia at the end of 1941 a neurosurgical team was authorised under Major I. D. Miller with permanent surgical and nursing assistants. This team was to be attached to the 2/9th A.G.H. and had no separate establishment. It was designed to deal with wounds of the head and spine and tumours of the central nervous system. Before this plan was implemented Major Miller was seconded to the British forces in the Middle East as the officer in charge of the neurosurgical centre for British forces at the 15th Scottish Hospital, Cairo. This arrangement held until the 2/9th Hospital returned to Australia. During this time only one Australian soldier was treated at this neurosurgical centre, all other head wounds in Australian soldiers being treated at the 2/6th Hospital at Jerusalem. Through the enthusiasm and perseverance of Colonel R. A. Money and his staff at the 2/6th Hospital this was recognised as the 2nd Head Centre by the D.M.S. at General Headquarters Middle East. The Australian neurosurgical team never functioned as such in the Middle East and on its return to Australia was disbanded.

No neurosurgical team was organised during the New Guinea and other island campaigns. A special neurosurgical centre was formed at the 114th A.G.H. at Tamworth, 280 miles from Sydney, in charge of Lieut-Colonel Miller, and here arrangements were made to treat all appropriate patients from New South Wales and Queensland. The amount of travelling necessitated made it impossible to send on all such patients, and in June 1944 the centre was transferred to Concord, Sydney, and attached to the 113th Military Hospital. In other capital cities neurosurgical work was carried out by specialist surgeons in the military base hospitals. Peripheral nerve injuries were not specifically directed to special centres, but came to the base hospitals. The great distances involved in the later island campaigns made it difficult to concentrate patients with any particular type of injury except in a reasonably central site. Naturally it was not desirable to transport all neural casualties to Tamworth, though application of a routine system of labelling patients for this hospital might have secured greater concentration. Thus the neurosurgical work was carried out in the Middle East and Pacific campaigns without a complete or central organisation.

It is therefore difficult to assemble comparable records of patients with central or peripheral nervous lesions. Nevertheless much useful information was gathered and disseminated and a steady evolution took place in surgical practice with regard to head wounds.

Further details may now be given of work done at a forward centre in 1941 and at base areas in Middle East in 1941. T. H. Ackland, in

describing the work of a forward team, pointed out how curious it is that only forty-six men with head wounds causing compound fracture of the skull were treated out of 2,767 admitted to hospital in six months. The difference in prognosis where the dura was penetrated was evident. Of eight men who had no dural penetration, all recovered, while of the thirty-eight whose dura was penetrated nineteen died. Of those latter only two died from meningitis, the remainder succumbing to injuries intrinsically severe. Since the operation centre could be reached in six hours from the front line, only a field dressing was usually applied. But where a delay of twelve hours or more took place before operation, a more detailed toilet of the wound was usually carried out. The first aid procedure was then to open up the wound and after guarding it with an acriflavine pack, to shave the skin for some inches round and paint with iodine. A fresh pad was retained in the wound by a dressing or possibly a few anchoring sutures.

At the operating centre few patients with head wounds had serious degrees of shock, and bleeding was seldom free enough to require transfusion. Special attention was paid to the degree of impairment of consciousness, which was, of course, of considerable prognostic value. Deep coma with disturbance of pulse and respiration usually meant a very bad outlook.

Operation was performed under local anaesthesia. The scalp was shaved and thoroughly cleansed; a steel helmet was found to make a convenient headrest. After narrow excision of the skin edges the bony damage was adequately exposed. If injury to venous sinuses had occurred enough bone was promptly removed to permit control of bleeding. Fissure fractures were left undisturbed. Depressed fractures were treated by removal of all loose and indriven fragments, so as to relieve pressure. If the dura was intact it was not opened unless signs of blood under tension were seen. When the dura was torn adequate exposure was made without enlarging the opening, but only superficial fragments were removed. The brain wound was gently irrigated, a sucker was not used and the dura was left unsutured. No sulphanilamide powder was applied locally. Drainage was used only for a brief period, and then only to prevent the collection of clot which might delay healing. If cerebro-spinal fluid gathered beneath the flap no action was taken as a rule; at the most it was aspirated if there was increasing tension. Lumbar puncture was not necessary.

During later actions in the desert Major I. D. Miller, A.I.F., attached to and commanding a British neurosurgical unit, had an opportunity of studying further head wounds as seen in a base area. The conditions were naturally different from those found in a forward operating centre; units moved rapidly, were not infrequently disorganised, and men were often out of touch with assistance for days in the desert or even were taken prisoner and then escaped. Fifty patients were treated at this neurosurgical centre after one engagement. One-quarter of these had infected wounds. That the percentage of infections was not higher was believed to be due in part to the administration of sulphonamides, and in part to early

correct treatment at forward centres. All patients were not so fortunate, but it became apparent that the period elapsing between the receipt of a head blow and treatment at a well equipped operating centre could safely be extended to two days or longer. Such patients travelled much better before surgical treatment than after, and a man in good condition easily travelled safely, even for twenty-four hours, with a first aid dressing only. Even after an interval of five days, successful operation has been performed. The real problem that arose from this series was how to prevent infection. The answer lay in measures designed to lessen the risk of the open head wound.

Infected wounds of the brain were due to foreign bodies, either metallic pieces of missiles or fragments of bone, or even unwisely placed gauze plugs. X-ray examination at the base showed deeply indriven foreign bodies in some instances, but with no evidence of infection. These deep foreign bodies were therefore best left alone, treatment being confined to the superficial parts of scalp, cranium and brain tissue involved in the injury. Experience with those patients who had a brain infection showed that superficial infection had occurred through ineffective treatment of the external wound. Abscesses and infected sinuses were not infrequently found when the patient reached the base area. Removal of the foreign body was then often a difficult and hazardous procedure, especially when the missile or bone fragment was close to a ventricle. *Fungus cerebri* was seen in five cases of this series, a considerable percentage. Correct treatment comprised attention to the general condition of the patient, specific treatment of meningitis if this existed, and if an abscess was suspected, sooner or later the hazardous procedure of finding and draining it. Abscesses were found in six patients of the fifty—a significantly high figure in a small series. Three of the fifty patients died, and two of these had brain abscesses.

Colonel R. A. Money and Lieut-Colonel T. Y. Nelson in the Alamein campaign, working at an A.I.F. general hospital, also collected their experiences of battle wounds of the head. Modifying Cushing's nomenclature, they classed their series of 78 cases as :

(1) Wounds of the scalp;
(2) wounds of the skull without depression of fragments;
(3) wounds with depression of fragments but without penetration of the dura;
(4) wounds with penetration of the dura and some brain involvement;
(5) perforating or "through-and-through" wounds;
(6) wounds involving the orbits, or accessory air sinuses or cells.

Of the 78 patients 25 had penetration of the *dura mater*. The special army form W3118B for head injuries was used in the keeping of records. They found that head wounds from the Western Desert could be safely left for three days or more before surgical attention was given. An interval of even ten days has not proved too long for full recovery. Wounds were frequently found to be sterile when sulphonamides had been given since the injury.

After radiological examination and careful preparation of the head, under local or "Penthothal" anaesthesia the necessary operative measures were carried out. Careful inspection for superficial foreign bodies was made, even in fissured fractures, where it was often advisable to make a burr hole to exclude the presence of effused blood. All accessible metallic and bony fragments were removed. Instances were encountered illustrating the important role that bony fragments may play in producing sepsis. The penetrating wounds of the skull caused most difficulty. Superficial debris, clot and destroyed brain tissue were gently removed by lavage or suction and indriven fragments gently extricated from the track of the missile. If possible, in the absence of established infection, the dura was closed, with a soft drain if the ventricular system was damaged. Sulphonamides were given by mouth, preferably sulphadiazine or sulphathiazole, though these were not always obtainable, and local application was usually made also. If meningitis or ventriculitis or infection of the brain substance followed, massive doses of sulphadiazine were given up to 12-18 grammes a day with adequate fluids.

Money and Nelson found that a delay of several days was not disadvantageous; much more important was the thoroughness of the first surgical procedure, especially in the removal of bony fragments and debris. They reiterate the warning of all neurosurgeons, that unilateral focal signs of damage to the brain are not an indication for operation in the absence of signs of compression. Australian neurosurgeons have all emphasised the importance of this concept, that focal lesions do not necessarily mean a bad outlook. A digression may be made here embodying this experience. War injuries of the head do not necessarily parallel civilian injuries. A high velocity missile on striking the skull has an enormous kinetic energy ($\frac{1}{2}mv^2$ as Money and Nelson remind us), despite its small mass. It may even glance off the skull and yet send a shower of bony fragments into the brain which may penetrate some distance. Focal injury due to this disruptive force may dominate the picture, though often consciousness is but slightly impaired. It is the exact converse to concussion from a blow. These focal disturbances may be transient or leave residua, and may be of motor or sensory type. The upper limb with its intricate relations with lower centres is vulnerable to such disturbances. Motor function has frequently been observed to be severely damaged in these war wounds and yet has made good recovery in many instances after a latent period, which is shorter in the lower limb than the upper, as W. Ritchie Russell has pointed out. Sensory disturbances have been less often observed, but the thalamo-cortical system may evince damage which appears usually to be at cortical level. In the case of vision, measurement of sensory loss is simple, and between the extremes of complete loss over part or whole of a visual field and transient loss only all grades may be seen. In post-central damage the interesting phenomenon of perverted sensation has also been noticed; it has on occasion been clinically troublesome. Study of these evidences of ballistic damage has emphasised the value of a conservative or hopeful outlook.

From Australian experiences in the Middle East, that is, up to the end of 1942, the following points emerged as significant in the treatment of head wounds. The conditions of the Western Desert were relatively favourable as regards infection of head wounds because most missiles inflicting recoverable wounds were small, and, incidentally, at a high temperature: infection came from indriven fragments and from secondary infection of the superficial wound. Except when the brain was compressed by concealed bleeding evidenced by loss of consciousness, there was no need for surgical measures till the man reached a stable area where he could be held. Superficial as well as deeper wounds required careful attention, as the onset of infection could cause necrosis of bone and extra-dural abscess or sinus thrombosis. Centres dealing with head injuries needed adequate facilities including Cushing clips, correct bone instruments and a suction pump, even if driven by foot power. Though X-ray equipment may not be essential in forward areas it is desirable. Bleeding may be arrested without electro-coagulation. Good clippers or razors for preparing the head, and a skilled hand to use them are of real importance. Finally, in contradistinction to wound treatment in general, wounds of the head should be excised and closed if possible.

Despite what has been said of the relatively clean terrain of the desert, it would be wrong to assume that infection was not a real danger. Miller in a series of fifty open head wounds received in a battle in the Western Desert found that 25 per cent were infected. This infection was encountered at all depths of the wound. Even simple scalp wounds left open at dressing stations and packed with sulphonamide powder or "Vaseline" gauze became infected, and took weeks to heal. So too, even small tangential wounds of the skull were sometimes found at base to display bare bone, and X-ray examination usually showed them to be comminuted and slightly indriven. The patients complained of local headache. Excision and removal of fragments permitted closure, and healing took place. All infected wounds of the brain were associated with foreign bodies, usually bony or metallic, though foreign bodies do not necessarily cause infection and may be left safely if deep and showing no surrounding reaction. Sometimes an infected sinus could be demonstrated leading to a foreign body which could be removed with special forceps designed to grasp without risk of pushing the object inwards. Five cases of *fungus cerebri* were seen, following severe penetrating wounds, all due to infection. The treatment adopted was that appropriate to the cause. After penicillin was introduced the treatment of meningitis was much more successful. Abscess formation was usually in the direction of indriven bone, sometimes beneath a *fungus cerebri,* and could usually be located by careful search with a brain needle, and aspirated repeatedly if necessary. Six abscesses were encountered. Miller comments on the high proportion compared with the figures of the 1914-1918 war, which in different series seldom exceeded 2 per cent.

Miller has summarised his experiences and views as follows:

"As the war continued there came about a change of mind in regard to the treatment of head wounds. In the early phase it was thought that any penetrating missile

must be removed in the early treatment. As, however, there were few surgeons competent to do this and they had not adequate equipment, most of these metallic missiles remained *in situ*. They were almost invariably associated with indriven bone fragments which were often sprayed like a jet into the cerebral substance. Most such wounds were infected when the patients reached the base, and either presented as abscesses or open discharging sinuses. It was then found that the indriven bone was always the causal agent and that if these could be removed the infection would usually subside and the metallic foreign body which might lie at a considerable distance could be left undisturbed.

There was a tendency at some forward dressing stations to leave head wounds open—packed with sulphanilamide and "Vaseline" gauze—a misinterpretation of technical instructions regarding wounds in general. This practice inevitably led to infection and often disaster.

The forward treatment of head wounds should be all or nothing. In this it is to be noted if a head wound is not interfered with, but merely covered with a sterile dressing it may be left fairly safely for 2 or 3 days before being submitted to routine debridement and closure. In the Libyan campaigns this was a very important fact to stress, as it was often several days before the wounds could reach a centre with competent treatment, but it was much better for them to be thus treated than to have less than adequate surgical tinkering at forward stations. In the British Army in the 2nd Libyan campaign instructions to this effect were issued and all head cases were boldly labelled and despatched to the centre in Cairo.

The first treatment of a head wound should be the last. It can however only be done properly by a surgeon with adequate neurosurgical training and with proper equipment. The essentials of such equipment are suction apparatus, electro-coagulation unit, and special neurosurgical instruments. It is of course possible for a mobile team to carry such adequate equipment."

Penicillin added greatly to the safety of deliberate manoeuvres, and was a powerful weapon against established sepsis. Previous experience had shown that sulphonamides, and in particular sulphadiazine, decreased the mortality of infected head injuries, and penicillin was a definite further advance. In the treatment of intracranial abscess, aspiration and instillation of 250 units of penicillin became standard practice. This was usually followed by prompt resolution and closing of sinuses leading to foreign bodies, even though the removal of the latter was still necessary. Patients were successfully treated with penicillin even when ventriculitis was present with or without rupture into the ventricular system. During the island campaigns penicillin made a great difference too in dealing with head injuries. The potentially dangerous scalp wounds could be closed with relative impunity, and the risk of infection tracking through fissures in the outer table of the skull was minimised, thus preventing its spread into the diploe and meningeal veins. Open head wounds could also be dealt with much more safely in a terrain more liable to hold and convey infections than the dry though dusty air of the desert. In fact, as in wounds of other regions, penicillin allowed surgeons to gain full advantage of those special principles applicable to the surgery of head wounds which had been learnt in earlier campaigns. In New Guinea and other Pacific areas transport of wounded was in places a peculiarly difficult problem. With head injuries this was not so vital as in abdominal wounds, where the safe time limit is brief. Provided men with head wounds could be brought to an adequately equipped centre within a few days, the result was usually

good, provided the wound was not of too severe a nature. But though the aftermath of wounds severely affecting the brain is apt to be unfavourable, focal damage, as previously pointed out, was not of itself an indication for interference, and spontaneous improvement or recovery often occurred.

Restorative surgery was sometimes necessary to make good large bone defects. The importance of deferring such operations until latent sepsis had disappeared is always stressed by neurosurgeons. A recommended manoeuvre was to subject the wound to vigorous massage for some days to ensure that no inflammatory reaction could be thereby excited. Penicillin greatly increased the margin of safety, and permitted much earlier intervention without risk, and even if some degree of infection occurred bone grafts retained their viability. The introduction of acrylic plates has to some extent reduced the necessity of using autogenous bone grafts, with the attendant difficulties of healing in the donor area, as when inner table ileal grafts were used for larger defects in the skull. However, technical difficulties in the taking of immediate casts for synthetic plates led to the use of bone.

REHABILITATION

Rehabilitation of patients after serious wounds to the head and brain is a most important branch of surgical care. Cairns and others have pointed out that early enlistment of the cooperation of the patient and if possible of his friends is advisable. The majority of men with recoverable war wounds made a good physical recovery, a fact which must be clearly recognised by the patient and his relatives. The speedy return of motor function, such as movement, speech and the performance of complex acts is in itself a fillip to full recovery, but it must be aided by correctly planned occupational treatment. A more serious bar to recovery is a degree of lowering of intellectual capacity; even the familiar fatigue and difficulty in concentration after head injuries only too easily lead to a listless outlook on active life. Headaches are common for some months, so too is some degree of dizziness. For these, simple treatment and reassurement are needed with graded and progressive activity. Medical officers, occupational therapists and Red Cross workers have been most useful in this work; it is important that they should be interested and well trained. It has been pointed out by neurosurgeons that the mere appointment of a "rehabilitation officer" in a medical unit is not enough; what is really required is a trained team.

Unfortunately the greatest gap in this last phase of readjustment to every day life has been in the liaison between civil life and re-employment. The value of continuity is well seen in one instance, that of a young soldier who had sustained a severe wound in the left temporo-parietal region. He had complete expressive aphasia, and complete right hemiplegia and astereognosis. Careful training over twelve months was successful in teaching him to speak and walk, and eventually he was able to take a secretarial position. This shows too how serious and irremediable and

wrong it is to regard such men as "permanently and totally incapacitated". It is of course admitted that the "stuff" of which the soldier is made in the moral sense is all important. From the beginning of the rehabilitation of men with brain injuries some assessment of their types of character and personality should be made and used as a guide to the means by which they may be directed along the path to recovery. The same applies to less severe injuries, in fact to every man who has had meningitis or concussion. In the Middle East an order was made for a time that every man who had cerebral concussion was to be kept three weeks completely at rest. The order was later rescinded, but surely as a fast rule it was a psychological error.

PREVENTIVE ASPECTS OF HEAD WOUNDS

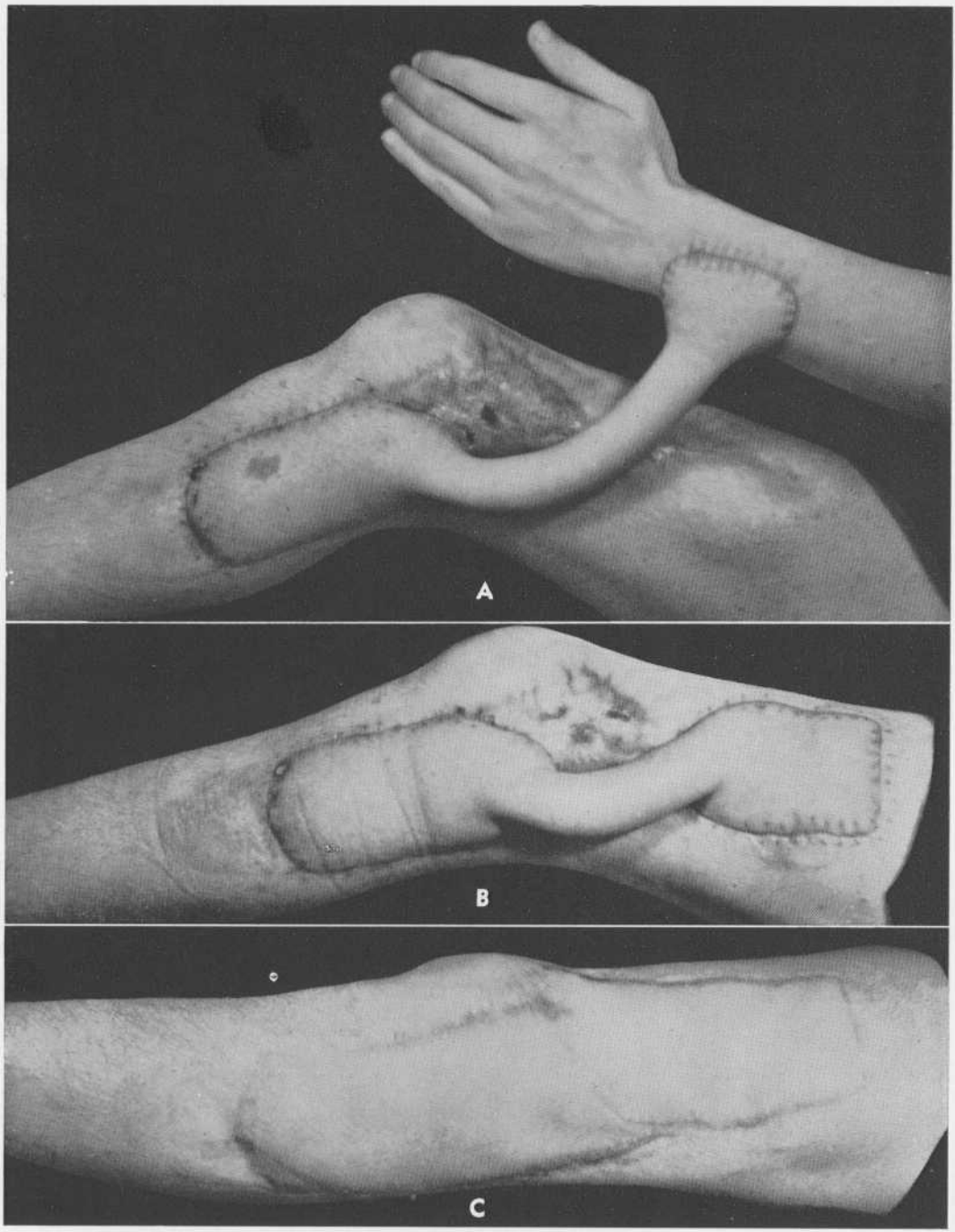
The steel helmet adopted by the A.I.F. has drawbacks. It was designed originally to protect against shrapnel and bullets, but as Money and Nelson point out these are less common causes of wounds than bomb splinters, high explosive shells and mines. A design which fits closer over the frontal, temporal mastoid and occipital regions would give greater protection.

More careful toilet of the head by soldiers is advisable too. Close clipping of the hair before action would keep scalps cleaner and would prevent hair being carried in by a missile.

The suggestion was also made in the Middle East that every soldier should carry prophylactic dose of a sulphonamide which may be taken, or administered by stretcher bearers, if he is wounded. Four to six grammes of sulphadiazine would be effective for twelve hours.

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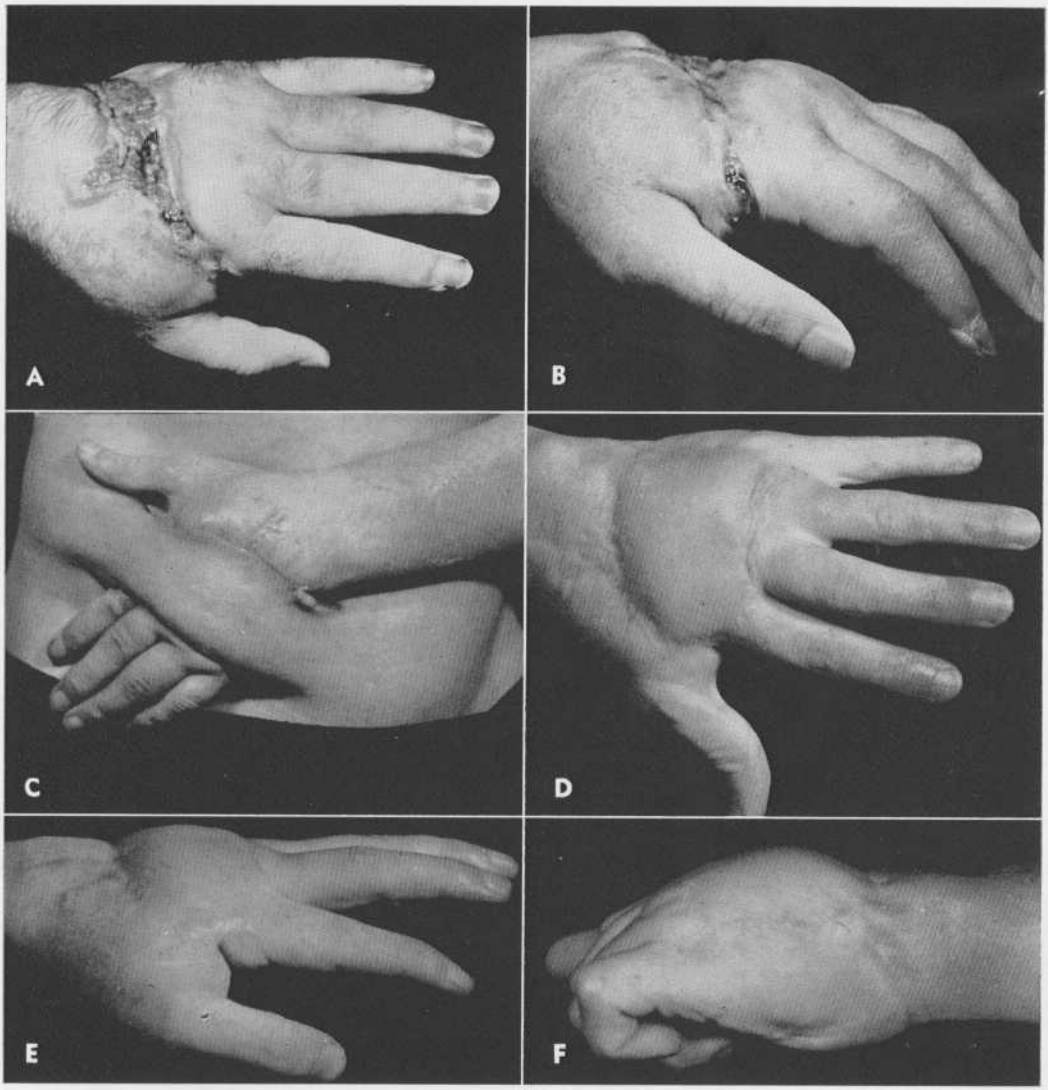
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(B. K. Rank)

Correction of scar disability in relation to nerve injury.

(a) (b) and (c) Final stages of replacement of an extensive ulcerating scarred area over the lateral aspect of the knee. There was a lesion of the peroneal nerve. Satisfactory operative procedures in relation to the nerve injury are rendered possible only by replacement of such scars.



(B. K. Rank)

Result after soft tissue reconstruction and multiple extensor tendon grafts for severe compound hand wound.

a) and (b) Gunshot wound of hand with soft tissue, bone and tendon loss.
(c) Interim stage of soft tissue repair.
(d) (e) and (f) Result after capsulotomy for fixed extension of metacarpo-phalangeal joints of 3rd and 4th fingers and subsequent extensor tendon grafts to the same fingers. The tendon grafts were inserted beneath the fat of the flap using the trochar and cannula method.

CHAPTER 43

INJURIES OF PERIPHERAL NERVES

PERIPHERAL nerves may be injured by open wounds inflicted by various weapons, or by damage caused by external violence of sudden or gradual application without concurrent injury to the skin. This latter variety may be produced by direct violence or compression, or by force acting at a distance, as in stretching or tearing injuries to a single nerve or a plexus. Injuries to bones or blood vessels may involve nerves, and may appear late in the history of an injury as the result of long irritation or pressure. A nerve may also be damaged by ischaemia following intensive or extensive tissue injury by wounds or burns. As will be seen later, myelinated fibres are particularly susceptible. More accurate physiological and clinical knowledge has been gained in recent years, and improvements in operative technique have in some measure kept pace with these, though no fundamental advances have been made. During the war an excellent illustrated memorandum on the diagnosis of peripheral nerve injuries was published by the Medical Research Council in England. This was very helpful, and clearly showed the various manoeuvres and tests by which loss of muscle function and other signs of nerve damage could be made manifest. The pitfalls of synergic or trick movements were described also, which can easily conceal the true scope of a nervous lesion. Diagnosis of peripheral nerve injuries included more than the information that a given nerve has been damaged: it is necessary to assess the type of injury and the extent to which it limits or destroys the function of the nerve. In this, electrical methods of diagnosis were of confirmatory value when available, as at the larger base institutions on such information prognosis to some extent depended. Electromyography has been found of value in the resolution of some of these difficulties. Accurate records have been found essential: the original history may contain the only record of the date and manner of the infliction of the injury, the presence of associated trauma, the signs and symptoms at that time, the sites of wounds of entrance and exit and the operative findings and procedure. The diagnosis of difficult conditions such as combined lesions, or lesions at different levels may be made even more obscure by the omission to send a complete record with the patient. It is particularly important to understand the actual anatomical condition of the damaged nerve and the neighbouring tissues. As is well known, concussive damage of a nerve without loss of continuity, is a common and favourable type of injury, in which complete temporary paralysis may recover entirely or with only slight loss of muscular power or with minor paraesthesia. Understanding of the principles involved is important in all who undertake the care of patients with these lesions, whether in forward areas or base hospitals. As will be seen, the modern safeguards against infection now permit more extensive procedures at forward bases under favourable conditions, but the base hospital remains

the chief centre for definitive and consecutive treatment. Nerve injuries may require appeal to a large number of experts. In Australia, as in England, orthopaedic surgeons have taken a great interest in this work, as is natural, for injuries of nerves frequently co-exist with injuries requiring orthopaedic attention. In addition to the orthopaedist and neurosurgeon, or general surgeon interested in this work, the help of the radiologist, the physiologist, the pathologist, the physiotherapist and psychiatrist may be required. Further, a long follow-up is often necessary, even up to periods of several years. At Heidelberg Hospital it was found advantageous to employ a junior medical officer for a period of twelve months or more for periodic checking of nerve injuries. This officer attended at the Repatriation Department by arrangement and there examined discharged men returning for observation or treatment.

TYPES OF PERIPHERAL NERVE INJURIES

The foundations of the modern management of injuries of the peripheral nerves were firmly laid in the 1914-1918 war, and recent advances in knowledge and technique have greatly clarified the problems.

Before the diagnosis of these lesions can be approached it is essential to have as a firm foundation a knowledge of the physiology of somatic peripheral nerves both in their intact state and during the changes incident on injury. Particularly is it important to be able to distinguish between damage of the supporting and the conducting mechanisms. The supporting tissues of nerves are merely areolar, but their peripheral condensation supplies the nerve with a sheath, the epineurium. If this structure remains even partly intact the process of regeneration is greatly assisted by its guidance and support. The conducting mechanism consists of the axonal fibril of the nerve cell and its insulating sheath of lipoid substance, myelin, and carries with it its own tough enveloping layer of neurilemma, composed of Schwann cells. All these components have important parts to play: the all-essential axon is functionless unless it preserves its continuity, myelinated nerves need their insulating coat, and the tubes of Schwann cells are specific conduits, linking each fibril with its appropriate endplate. The nerve fibril varies in size with different nerves, and with this variation are associated quantitative differences in functional activity. Thus, excitability, conductivity, wave amplitude and sensitivity to trauma all vary with the type of fibril. Efferent motor nerves and those carrying proprioceptive impulses have large fibrils of high functional activity, and are very sensitive to injury. Less sensitive are the afferent thermal and tactile nerves and also the post-ganglionic fibres, while the pre-ganglionic non-myelinated nerves with small fibrils are still less sensitive to injury. In the testing of the functions of nerves suspected of injury these considerations must be remembered. The types of nerve injuries must then be distinguished according as both the supporting or conducting tissues are damaged, or the conducting only.

COMPLETE DIVISION OF BOTH CONDUCTING AND SUPPORTING MECHANISMS (NEUROTMESIS)

This lesion produces a familiar picture seen when a nerve is completely severed, as in an open wound, or by excessive tractive force. The well-known Wallerian degeneration takes place in the axons, and the myelin sheath becomes fragmented. The length of nerve involved in the injury is important. Clean incised wounds may affect only 1 to 2 centimetres of the nerve, but traction lesions may involve 15 to 20 centimetres of the proximal nerve stump. The effect on prognosis of this functional gap is obvious.

Meanwhile, prompt proliferation begins in the axons on the proximal side of the gap, and also in the neurilemmal cells, which form tubes along which the regenerating fibrils grow. Proliferation of the Schwann cells and the continuity of this layer are essential to nerve regeneration. Therefore regeneration is not seen within the central nervous system or the optic nerve, where neurilemma is absent. At the cut surface the new fibrils find a generally centrifugal direction, seeking neurolemmal tubes in the distal end of the cut nerve. Decussation of the fibres takes place, as in the course of their growth many of them are directed laterally. Superimposed on this fibrillar regeneration is the fibroblastic reaction of the areolar sheath, and by the conglomeration of the elements of these two reactions is formed the familiar neuroma or bulb on the proximal end of the severed nerve. In the distal part of the nerve the axon degenerates and great neurilemmal activity produces a glioma, about half the size of the neuroma.

It is evident that these activities represent an end state resulting from failure of the nerve to reunite: successful regeneration demands that the growing fibrils at the near end of the site of division of the nerve should find their neurilemmal tubes at the farther end. This can occur only if the ends of the nerve are approximated and if they have not undergone rotation. Lack of success causes "confusion" at the line of division. Avoidance of confusion depends upon the integrity of the supporting mechanism: the surgical implications of this are evident. It will also be clear that traction lesions are particularly unfavourable for regeneration, by reason of the extensive damage and degeneration of the conducting mechanism, often far beyond what appears to the eye, and the severe trauma of the supporting structures, which allows wide separation of the nerve ends. The outlook is therefore serious and often hopeless.

PARTIAL LESIONS OF CONDUCTING AND SUPPORTING MECHANISMS

In these less severe forms of combined damage portion of the nerve remains intact. Therefore degeneration and its attempted repair affect the interrupted structures only. The proximal neuroma and the distal glioma are segmental. At operation the affected area can be detected by palpation

along the nerve trunk, and even on clinical examination pressure may elicit paraesthesia which gives a useful clue. In traction lesions the neuroma and glioma may be separated by a long strand of fibrous tissue, so that the nerve presents the macroscopic feature of a long ovoid thickening. If the injury or fibrosis produces much confusion at the site of injury of an important nerve, the nature of the disability will depend on the function of the fibres affected. The implication of these findings on treatment are dealt with later.

COMPLETE LESIONS OF THE CONDUCTING MECHANISM (AXONOTMESIS)

Lesions affecting the conducting mechanism differ only in important regards from the types just described. Complete interruption, without severance of the supporting tissues, may be caused by direct compression of the nerve trunk, or by traction, or may result from the blunt injury sustained in fractures or dislocations. In these injuries the supporting structures may remain more or less intact: if so, regeneration is much facilitated, and confusion at the line of interruption is minimal. Continuity of the nerve is not lost, nor is there any rotation at the line of division, and the rate of recovery will then depend on the rate of fibrillar regeneration. A minimal degree of confusion makes perfect regeneration a more practicable result, but deterioration may occur in proportion as the supporting areolar tissue is damaged.

PARTIAL LESIONS OF THE CONDUCTING MECHANISM (CONCUSSION OR NEURAPRAXIA)

These lesions are usually due to concussion from the effects of high velocity missiles, impingement of blunt objects or bone fragments, compression by a tourniquet, bandage or splint, or ischaemia of a limb. Neurapraxia is the commonest of all nerve lesions: it occurred even in debilitated patients suffering from typhus and other infections, induced by trauma of the slightest and often unnoticed type. It has long been suspected that the intimate fundamental lesion is degeneration of the myelin sheath, with an intact axon. The tough neurilemma preserves its integrity also. Recent work appears to substantiate this. The absence of axonal degeneration distinguishes this lesion from axonotmesis; therefore no regeneration of the axon is necessary for recovery of function of the nerve.

Though these four types of the traumatic lesions of nerves are distinct, and may often occur and be recognised as separate entities, a combination of them is not uncommon, particularly in lesions of the plexuses. Trauma due to traction, for example, may produce a puzzling mixture of clinical features due to the simultaneous presence of several types of injury in different nerves. In these complex clinical pictures neurapraxia often plays an important part. It will be evident that regular and repeated examination alone can guide the surgeon.

THE RATE OF REGENERATION

When the nerve fibrils have undergone degeneration the rate of regeneration will be determined by the rate at which the fibrils growing from the proximal end will reach their peripheral terminals. The completeness of the recovery depends on the proportion of fibrils which enter their corresponding neurilemmal tubes. A high degree of confusion of the fibrils will of course produce a poor result. Perfect recovery cannot be expected in complete lesions of mixed nerves. The rates of recovery of divided nerves vary. The usually accepted rate was given as 1 millimetre a day, but during the war Seddon and others subjected this to review. A lag period precedes the penetration of the distal neurilemmal tubes by the proliferating fibrils. This period varies with the local conditions at the site of injury, being least when the supporting tissues are intact. It may persist for two or three months if conditions are unfavourable. The time expected for regeneration to take place must also include the time occupied by the fibrils in traversing the distance from the site of injury to the peripheral end structures. Tables have been constructed giving average or approximate distances from a fixed point on the upper and lower limbs to the entry of motor nerve branches into muscles. By calculations on this basis it has been found that the rate of recovery falls away progressively as the process nears completion, but the rate of regeneration averages 1.5 and 2.0 millimetres a day in motor fibres after suture, and probably rather more in the smaller types of fibre.

Tinel's sign ("*le signe du fourmillement*") has been employed as an index of regeneration, the distal tingling sensation produced by tapping the injured nerve being used as an evidence of functional recovery. It has been considered of confirmatory value of regeneration, but an unreliable measure of its rate. Modern opinion is very sceptical of its use.

The value of some standard by which regeneration can be estimated is of considerable practical importance, as on this often rests the decision as to surgical exploration. As will be seen, different nerves vary in their regeneration times, introducing another complicating factor.

CLINICAL SIGNS OF NERVE INJURY

The diagnostic signs of peripheral nerve injury were admirably covered in the Medical Research Council's memorandum. The object of seeking and interpreting these signs is obviously to ascertain if a peripheral nerve lesion is present and if so what is its site and its nature.

Disturbances of function are simply divided into two categories (1) loss of function, (2) perversion of function. Loss of function in efferent nerves may be manifested as muscular paralysis, or as paralysis of the sudomotor, pilomotor and vasomotor functions. In afferent nerves it takes the form of loss of sensation to touch, pain, heat and cold, vibration, posture and deep pain and pressure. Perversions of function may be shown in efferent nerves as muscle twitching or fibrillation, muscle spasm, abnormal sweating and vasomotor disturbances. In afferent nerves these appear as para-

esthesiae, phantom sensations, spontaneous pain, pain of abnormal type, not previously experienced, or abnormal thermal sensations.

Loss of function is seen in its entirety where nerves are completely severed. Aberrations of function are not uncommon. The curious and uncomfortable sensations felt in the field of regenerating cutaneous sensory nerves are familiar to many people. Their more troublesome varieties are most often found after lesions of certain nerves, particularly the sciatic, the posterior tibial and the median. Why these nerves are prone to these disturbances is not clear. They also occur in well marked form in partial lesions associated with intraneural fibrosis, the perverted sensations arising in that part of the nerve which is anatomically intact. These features add to the difficulty of diagnosing the type of a lesion, whether partial, affecting the conducting mechanism alone, or a recovering lesion.

Recovering lesions show a progressive centrifugal restoration of function, and though muscle recovery and sensory recovery are in the correct anatomical order, interpretation is not always simple. For example, when some fibres of a nerve are severed and others merely compressed or concussed, recovery may occur promptly in part of the nerve's distribution, but may lag in other parts whose fibres have to regenerate.

Neurapraxia, representing about 80 per cent of the peripheral nerve injuries of war, in its rapid and satisfactory recovery shows the following features:

1. Motor paralysis is nearly always greater than the sensory, and is usually complete.
2. There is little or no muscle wasting, except such as may be associated with concomitant injuries of the bones, tendons or muscles.
3. Electric excitability of the nerve is unchanged.
4. Proprioceptive sensation is more deranged than cutaneous, and far more than in degenerative nerve lesions.
5. Mild irritation phenomena are common but do not persist.
6. Motor recovery is rapid and complete but follows no anatomical pattern; it occurs either irregularly with slight lags from one muscle to another, or in all muscles simultaneously.
7. Cutaneous sensibility is often only incompletely affected; some finer discrimination may be lost at first, but some sensation is usually present. Recovery is rapid and complete.
8. The rate of both motor and sensory recovery is so rapid as to preclude any possibility of Wallerian degeneration.

The greater loss of deep proprioceptive sensibility than of cutaneous sensation is characteristic of neurapraxia. Reversal of this finding indicates rather axonal degeneration. The duration of symptoms varies greatly, from a few hours to six months, and no apparent correspondence exists between the degree of the disability and the type of injury. Usually recovery is complete by the fourth month.

Response to electrical stimulation is still found useful. An intact nerve will of course transmit faradic impulses and produce strong muscular contraction. A degenerated nerve will not transmit either faradic or galvanic

impulses. A degenerated muscle will, however, respond to galvanic stimulation by a slow lazy wave-like contraction. This reaction of degeneration (R.D. i.e. absent faradic responses and slow abnormal snake-like muscle response to galvanic stimulation) does not appear until the second week after axonal degeneration. Neurapraxic lesions do not show any reaction of degeneration; nerves which have sustained axonal injury show the reaction of degeneration in those fibres affected.

The first sign of electrical recovery in lesions of the conducting mechanism is a galvanic response to a smaller milliamperage than was required previously. The response next becomes more brisk. This is followed by return of clinically detectable function, and a considerable amount of voluntary movement may have returned before a reaction to faradic stimulation is obtained. Thus, if the galvanic stimulus produces no response, irreparable muscle degeneration has occurred and nerve regeneration is valueless from the viewpoint of motor function. If, during this third week, however, the nerve responds to faradic stimulation of normal intensity, the prognosis is good, as the lesion is neurapraxic.

Thirdly, investigations of a special type are indicative of the proper state of affairs within the nerve.

If concentric electrodes be placed proximal to the site of the lesion and a faradic current twice that required to produce a response in a normal nerve applied, a contraction will be obtained in several muscles below the lesion if the type of lesion is neurapraxic. In these cases no voluntary contraction can be obtained, despite the fact that the axons are intact.

This finding may also be confirmed by electromyography. At rest the concentric needle electrode transmits no impulse to the oscilloscope (i.e. "tone" is absent). However, on attempted voluntary contraction (which does not occur) a burst of motor unit action potentials is obtained. Thus in neurapraxic lesions voluntary impulses can get past the lesion, but not in sufficient quantity to produce voluntary movement.

The late results of degeneration of muscle deprived of nerve supply are familiar. Atrophy occurs, and may be complete: muscles shorten, and contractures may form. These changes vary with different nerves and with such factors as age, debility and sepsis.

The sensory features found in the various types of lesion are of both localising and diagnostic value. Sensory changes are complete if the axon has degenerated, but are variable in neurapraxic lesions in which the deep sensory changes often overshadow the superficial. The anaesthetic field demonstrable in axonal degeneration contracts after a time, independently of regeneration of the axon. This phenomenon is ascribed to the ingrowth of fibrils from adjacent sensory nerves; it is an identical process which accounts for the development of sensation in the skin of free grafts and pedicles.

Sweating gives useful objective information. In partial lesions hyperhidrosis often occurs, and may extend beyond the area of sensory loss. Anhidrosis is observed in denervated skin, and is an excellent index of loss of sensory function. Guttmann's Quinizarin test is valuable, and by

colour changes induced by sweat in a special dusting powder clearly indicates the affected areas. Vasomotor effects of nerve injury are most marked in sciatic, median and ulnar lesions. Nutritional changes may occur, usually in denervated areas in which irritation and pain have occurred.

CLINICAL SIGNS OF RECOVERY

Most of the signs of recovery of damaged nerve function are implicit in what has already been described. The progress of motor recovery as estimated by repeated and recorded examinations is an important sign, and may be supplemented by electrical methods. It is important to realise that the latter will notify the surgeon of recovering function before voluntary movement returns, though some movement may be detected before a faradic response can be obtained. The proximal muscles show returning contractible power before the distal. Sensation is usually gained for pain earlier than for touch, and at first is intensified, and tends to be referred to the distal parts affected.

It has been found advantageous for the patient to be under the continuous observation of one surgeon if this is possible. Not only are the observations likely to be more consistent, but the question of whether exploration should be undertaken or not can thereby be better settled. In June 1941 the Director of Medical Services in the A.I.F. in the Middle East gave instructions that divided nerves were not to be sutured, but that the patients were to be returned to Australia. The object of this instruction was not only to obviate risk of sepsis and to allow a safe period to elapse, but to ensure continuity of observation and treatment.

SURGICAL EXPLORATION

Theoretically the issue seems clear that neurotmesis partial or complete should be explored, that neurapraxia uncomplicated by other tissue lesion should not be explored, and that axonotmesis calls for exploration only if dense scarring is thought to be a barrier to regeneration. It may be remarked in passing that neurolysis, or freeing the nerve from adhesions, is not always successful or even necessary. The practical problem of exploration is not so simple as a dogmatic statement makes it appear, as it is complicated by many variable factors, and diagnosis, on which the decision rests, is often obscure.

A clinically complete lesion in which the nerve is believed to retain its continuity, that is, a neurapraxic lesion, should be given sufficient time to show signs of regeneration. After three or four months if there is no evidence of recovery, exploration is indicated. Sunderland has, however, given this caution: "There can be no greater tragedy in peripheral nerve surgery than the excision of an injured segment with end-to-end repair in a nerve that would have recovered spontaneously". If, however, the nerve is known to be severed, partly or entirely, operation may be undertaken as soon as local conditions are favourable for repair. In the series collected by Sunderland good results were obtained by repair up to eleven

months after the division of a nerve, but on the other hand, the surgeon feels that he should not wait till muscular atrophy has occurred or till neuronal and neurilemmal degeneration has taken place, making the likelihood of a satisfactory end result remote. In a large important nerve like the sciatic the responsibility is great. Even though voluntary contraction may be regained in part even after three years, the indication is to help start the process of regeneration as soon as it is known to be necessary and safe. Modern methods, in particular the use of sulphonamides and penicillin, greatly reduced the incidence and risks of sepsis, and so encouraged earlier intervention.

The question of primary suture *versus* early secondary suture has to be answered too. Results recorded in literature do not help greatly, for it is seldom that all the factors are stated. The nature of a wound, the presence of trauma to other structures, in particular bones and blood vessels, the existence of sepsis, and the variables introduced by the nature and degree of the nerve injury, the condition of the nerve ends and even the identity of the nerve itself, all modify the statistical trustworthiness of records when taken as a guide to action. Primary suture has some drawbacks, such as the unknown tissue reactions which may occur, and the inability to mobilise the nerve so freely as would be possible later under selected conditions. However, war experience showed a greater tendency even for the conservative surgeon to explore important nerves if this was clearly indicated and conditions at primary operation were favourable. Some of the types of injury seen in civil life fulfil these conditions, and immediate suture is likely to be undertaken more frequently with prospect of success. Lieut-Colonel Starr, summing up the procedure commonly employed by surgeons in the closing phase of the war, has stated the position as follows:

"Three main trends were evident in the development of the management of wounds involving nerves.

Firstly, exploration of the nerve was usually not undertaken unless it presented in the wound. Delayed primary suture of the wound under chemotherapeutic protection was performed. The outcome of nerve recovery was awaited before a decision to explore was made. As neurapraxic lesions have as a rule made recovery, and axonotmetic lesions have made partial recovery by the fourth month, all nerves not showing recovery at this juncture were subjected to exploration. The exception to this rule is the high lesion of the sciatic nerve, which must always be visualised before awaiting the outcome of nerve recovery. The same procedure was followed when the patient was first seen after the wound was healed, and the exact nature of the nerve lesion was in doubt. This procedure was most commonly followed by war surgeons.

Secondly, all important nerves in the region of the wound were explored to determine their continuity. No endeavour was made to perform suture, although this project was undertaken in a divided nerve two or three weeks after the wound had healed. There was a more noticeable bias towards this method of management in the Borneo campaign.

Finally a more enterprising school believed that chemotherapy afforded such protection that bone fixation (even by graft) could be justifiably combined with nerve, tendon and delayed primary suture during the first week after wounding. The results of this modern radical approach must await final appraisal before a final judgment can be given."

When the nerve has been exposed at operation the action to be taken must then be decided. A damaged but not severed nerve may assume various appearances. It may look and feel normal, apart from slight epineural thickening. It may be slightly narrowed or swollen, but with a patch of indurated tissue indicating the presence of scar tissue. It may show a smooth spindle-shaped swelling, little if at all firmer than usual, i.e., a fusiform neuroma, or else a lateral neuroma may be found. Such findings, though not associated with anatomical discontinuity, are indications of some degree of division of the nerve. Absence of neuroma or fibrous induration calls for conservatism, for the lesion is probably axonal only. On the other hand the presence of neuroma or induration calls for a decision whether resection and suture should be performed. If these manifestations are extensive further action is indicated, but in lesser injuries the circumstances must decide the wisest course.

NERVE SUTURE

The technique of exposure of peripheral nerves need not be detailed here: its description by Sir Harold Stiles in the Robert Jones Birthday Volume is worthy of close study. Since the amount of damaged nerve tissue varies with the type of wound or injury, so the approximation of the divided ends will vary in difficulty. Seddon has estimated the maximum defect in the nerve permitting repair without undue traction as not exceeding 6 centimetres. This applies to all major nerves except the ulnar and median. The ulnar nerve by transposition can be approximated even over a gap of 11 to 12 centimetres; the median over a gap of 7 to 8 centimetres. Neurolysis, or stripping the nerve from its fascial bed proximally and distally, can be safely done for a considerable distance. Careful use of the back of the knife thus frees the nerve, all branches being saved and likewise freed. Mobilisation of 20 centimetres of nerve does not appear to endanger end-to-end suture. This manoeuvre lessens any existing gap between the ends, which may be brought still closer by posturing the limb so as to relax the nerve. Such posturing must avoid any high degree of flexion or extension of joints which may be in itself harmful, both to the limb and to the sutured nerve which must be subjected to strain during the post-operative period. Care is of course necessary to ensure that in the subsequent mobilisation of the postured limb any manoeuvres are carried out gradually over a period of several weeks. In the repair of nerves like the popliteal and median, joint function may be impaired by extreme positioning and the operation rendered useless.

The condition of the nerve ends is most important. The ends must be healthy and free of scar, and in suturing them it is not only essential to avoid tension during the healing period, but also to perform the union without rotating the ends of the nerve. Trimming the ends is best done with a razor blade of wafer type, and aims at exposing a clean end with the funiculi visible and the sheath retractable. Sunderland has pointed out that there is a wide range in the amount and distribution of intra-neural connective tissue in different nerves, and that great care is necessary to

ensure that normal tissue is not unnecessarily resected. The arrangement of the funiculi and their investment may differ enough in a short distance to make recognition of the corresponding structures in both ends a matter for caution, in which some form of magnification may be helpful. Corresponding funiculi are identified, a *vas nervorum* in the sheath often giving a useful landmark, and guy sutures are inserted while the nerve is finally united. Materials for suture are preferably non-absorbable, usually silk, preferably white, nylon, tantalum or for fine nerves human hair, as in Starr's successful case of suture of the facial nerve. It is desirable to bring the epineurium together without gaps, so as to avoid the escape of nerve bulbs. Suturing should be as atraumatic as possible. Fibrin has been used to glue the suture line, and to make a casing for the repaired nerve, but no useful Australian experience can be quoted. Sometimes the gap between the ends of a divided nerve is too great to be compassed even with the manoeuvres described. In certain lesions the only alternative is some orthopaedic procedure such as tendon transplantation. Nerve grafting, homogeneous or heterogenous, may also be performed. This procedure was in an experimental stage at the end of the war, in spite of much work done on the subject for a number of years. No conclusions can be presented from the experience of Australian war surgeons.

Post-operative treatment in the first place ensures that the limb is kept in an appropriate posture until union of the nerve is firm, a period of three to six weeks. All movements of all available joints must be maintained. Active and passive physiotherapy is necessary to ensure good mechanical function of joints and muscles. It is particularly important to see that muscular paralysis due to a nerve lesion does not produce contraction and deformity of joints. All splinting must take this into consideration, and the position of rest of large joints should be maintained as far as possible. The hand and the foot are particularly vulnerable to damage through faulty posture and poverty of movement. In the chapter on injuries of the hand the subject is more fully treated. Individual nerve injuries demand individual methods. In ulnar lesions the "knuckleduster" splint was useful to flex the proximal and extend the distal finger joints. In median paralysis the thumb must be kept in opposition, and adduction avoided, so as to prevent the thumb from assuming the simian position.

RESULTS OF TREATMENT

It is difficult to assemble information about the results of treatment of nerve injuries, especially in statistical form. Many of the published series of results of expectant treatment or suture cannot be mutually compared because the conditions of the patients and of his particular injury are widely different. A further difficulty is that alluded to previously, the necessity for observation of patients over a period of several years, and for keeping records made by the same observers. It has not been found possible to follow up accurately all the patients seen and treated at the repatriation hospitals and clinics. Examination of the records confirms the value of conservative measures in the lesser neuropraxic lesions, and some-

times too of neurolysis where indicated. Some of the results of nerve suture have been satisfactory; these depended not only on the seriousness of the lesion and the nerve affected but also the degree of accompanying damage, particularly to blood vessels. Sydney Sunderland has published an analysis of 301 cases of injury of peripheral nerves (1945) and in more extended form (1947) a review of 339 such injuries in 294 patients observed for periods up to six years. He concluded that the results of a conservative policy were unexpectedly good, for 68 per cent of the entire series recovered spontaneously. After exploration 17 per cent were sutured, 1 per cent grafted, 1 per cent freed from pressure of a cervical rib, 6 per cent made a later spontaneous recovery, and 6 per cent were found to be hopelessly damaged. Spontaneous recovery occurred most frequently from lesions due to projectiles, though in many of these the nerve showed signs of severe interruption of conduction. He further concluded that exploration was desirable if circumstances were favourable, but that the continuity of a nerve should be preserved at operation, with the proviso that, should no signs of recovery appear after 6 to 9 months, re-exploration should be undertaken with a view to repair. Sydney Sunderland has also published a very full account of 59 patients treated at the 115th (Heidelberg) Military Hospital for injuries of the peripheral nerves. These men were observed during the years 1941-1946; most of them for a period of three to four years after suture was carried out. More than a general analysis was made, and condensed but full case histories are given in this contribution.

In this series the radial nerve was injured in ten cases, the median in fourteen, the ulnar in twenty-six and the sciatic and its popliteal divisions in nine. Of the radial injuries four resulted in good and one in satisfactory motor function. Sensory recovery was unsatisfactory. The fourteen median injuries on the other hand were characterised by useful sensory recovery. Motor recovery in these was good in three, satisfactory in four, fair in two and poor in two. The ulnar injuries were, as has been remarked before, commoner than any other type. Six gave good motor results, five fair and the remainder were unsatisfactory. Only two good sensory results were noted and ten partial; in the remainder of cases the condition was unimproved. The sciatic group of nine included two nerves sutured after seven and twelve months. Three motor results were good, two fair, and in three cases there was no improvement. A useful degree of sensation returned in some instances. Sunderland points to his detailed histories to illustrate the individual differences in patients, in the nerve damaged, in the level of its damage, and other details of the particular injuries. Certain generalisations were possible. In lesions in continuity resection and suture were indicated only when no sign of returning conduction was evident after six to nine months. A completely severed nerve should be sutured immediately local conditions were favourable for repair. In fact, immediate repair was advised if the nerve was cleanly divided and local damage was likely to cause only minimal scarring, if the nerve ends could be easily found and securely sutured without mobilisation or tension, if post-

operative posturing would not complicate repair in any way, and if there was no infection.

Secondary repair was thought to be indicated if the involvement of the injured nerve in scar tissue was expected, if the full extent of damage to the nerve could not be determined, if it was expected the extensive resection of the nerve would be necessary perhaps with special posturing of the limb to overcome tension, and if infection was present. Operation would be undertaken only when conditions were considered favourable.

Resuture was regarded seriously, particularly if some recovery had taken place, as no guarantee could be given that the patient's condition would be improved. Resuture might, however, be justifiably performed if the previous suture line had been disrupted or if failure followed operation under apparently ideal conditions, as there was nothing to be lost.

Observations on the course of recovery showed that improvement might continue for long periods but becomes stationary by the fourth year. The speed or sluggishness of the appearance of signs of recovery gave no indication of the prognosis. The fact that good recovery may follow a slow start of regeneration shows how important it is not to hasten suture or resuture unduly. In the median and ulnar nerves cutaneous sensation usually appeared in the hand before motor power, but residual defects were common, especially of joint sensibility. This defect greatly lessened the usefulness of the motor power regained in the hand. Gunshot wounds often produced laceration of nerves, and the resultant gap in continuity militated against full recovery. Retrograde neuronal degeneration occurred too, with detrimental results.

Some important findings are those concerning the power of the proximal stump to regenerate after long periods. This power has been shown to be fully retained after eleven months. The distal stump likewise retains its capacity to receive and transmit regenerated fibrils for a similar period. Muscle can regain its function after at least twelve months of denervation, provided appropriate interval therapy has been employed. Repair after long periods did not seem to differ in any way from that observed after prompt repairs. It is not surprising that distal muscles recover less satisfactorily than proximal after injury at a high level. Infection and scarring naturally imposed greater obstacles to a good repair; the length of nerve requiring excision was longer, and the bed carrying the suture line was adversely affected. The effects of sulphanilamide powder on nerve repairs were observed: moderate amounts did not appear to be harmful.

Another interesting series was reported by the A.I.F. medical services in Changi, Singapore. During 1943 all patients with nerve injuries received during the action of 10th January 1942 to 15th February 1942 were reviewed. The observations made in January 1943 were compared with previous records and again checked in September 1943. The injuries observed and results obtained were recorded in a table (appendix).

It will be seen that the ulnar nerve was frequently injured, and that the number of sciatic and lateral popliteal lesions was large in proportion.

SEQUELAE

Apart from such sequels as paralysis of muscles or loss or normal sensation, the most important residual symptom associated with peripheral nerve injuries is "causalgia", as it was named by Weir Mitchell.

Though the number of patients suffering from causalgia following war wounds involving peripheral nerves does not appear to be large, it is not negligible. Among 278 patients treated for primary nerve lesions observed by S. Sunderland and M. Kelly 34 suffered from causalgia. Four men under treatment had bilateral lesions, making the real total 282. Analysis of the patients suggested that, while causalgia is primarily a sequel of gunshot lesions, stretch of the nerve seems an important factor. The relative frequency in different nerves was as follows: in the sciatic nerve 16 out of 49 lesions; in the lateral popliteal branch 1 out of 15; the median popliteal 0 out of 3; the brachial plexus 5 out of 25; the median 6 out of 42; the radial 2 out of 46; and the ulnar 1 out of 64. Only 3 cases of causalgia occurred among 23 combined nerve lesions.

The nature of pain was commonly but not invariably burning; tingling, cutting or tearing types of pain were also experienced. Hyperalgesia was also common. The site of the pain was always in the hand or the foot. Many patients stated that they had felt the same pain since the time of wounding. Several factors were responsible in initiating attacks; these were activity of the limb, activity in the central nervous system, fatigue and distant stimuli which might be visual, auditory or psychic.

The preponderance of sciatic lesions was unusual, 17 out of 34. In general, pain more commonly arose from high lesions than from lower. The extent of damage to the nerve appeared to influence the occurrence of causalgia: it was pre-eminently associated with battle casualties in this series. Trophic lesions were more frequently seen in limbs in which causalgia had followed complete severance of the nerve. Sympathetic nerve involvement was evidenced by sweating and flushing of the affected extremity. Sunderland and Kelly concluded that clinical evidence suggested that causalgia was due to a spread of damage to the central nervous system by retrograde and transneuronal changes. A centre of abnormal activity in the spinal cord could act spontaneously as a disseminator of influences within the cord, and thus produce hyperalgesia in the periphery and spontaneous pain sensation in the brain.

The duration of causalgia is of great importance. In this series in 15 of the 34 patients pain disappeared, except for occasional isolated attacks, in from 5 to 13 weeks, in 8 patients after 13 to 26 weeks, in 8 from 26 to 52 weeks, and in 3 from one to two years. Spontaneous cure usually takes place, as these results show, and therefore surgical intervention should be reserved for patients with severe and prolonged pain. Surgery has not given good or enduring results in the past; only the more radical measures such as ganglionectomy seem to have been effective, but recent opinion favours preganglionic sympathectomy. No evidence can be produced here concerning the value of these procedures during and since the war.

The psychological factor calls for a further mention. The connection of this type of pain with battle casualties, study of the patient in relation to the background of his injury, and observation of his subsequent progress suggest that there is a psychic factor of importance. Yet there is no question of the reality and often the severity of the pain, or of the significance of the physical conditions surrounding the severance and repair of a main neural pathway to such essential structures as a hand or a foot. It might perhaps usefully be suggested that insistence on a purely psychic causation or on the predominant influence of a severe injury represent extremes which are equally undesirable. Without suggesting a close analogy, physicians may perceive something akin to post-herpetic pain in causalgia. Certainly the more it becomes established, the more difficult it is to cure.

APPENDIX

Summary of Nerve Injuries

Nerve	Case No.	Paralysis Complete	Paralysis Partial	Treatment To Nerve	Result Recovery	Result Partial Recovery	Remark
BRACHIAL PLEXUS	1	5th, 6th 7th dors.		Immediate suture		+	
	2	5th & 6th dors.		Nil		+	
ULNAR	3		+	Nil		+	
	4	+		Late suture—Suppuration of wound	—		
	5	+		Late suture of nerve	?	Not followed up	
	6	+		No operation		+	
	7	+		Late suture		+	
	8		+	Late removal of small fb from nerve		+	
	9		+	No operation	+		
	10	+		Late opn. large gap Autogenous graft	—		
	11		+	Neurolysis		+	
	12	+		Neurolysis	+		
	13	+ at wrist		Late suture	—		
	14	+		Late suture		+ (sensation only)	
	15	+		No operation	+		
MEDIAN	16	+		Late suture		+ (sensation only)	
	17	+		Gap too large—Suture impossible	—		
	18	+		Neurolysis		+	
	19	+		Neurolysis		+	
	20	+		Neurolysis—Later tendon transplant		+	
	21	+		Gap too large—Suture impossible	—		
	22	+		Late suture		+ (sensation only)	
	23		+	No operation on nerve	+		
	24		+	No operation	+		
RADIAL	25		+	No operation	+		
	26		+	No operation—Fracture unhealed	—		
	27		+	No operation	+		

	28		+	No operation	+	
	29		+	No operation	+	
	30	+		No operation	+	
	31		+	No operation	+	
	32		+	No operation	+	
	33	+		No operation on nerve Later tendon transplant	—	
SCIATIC	34	+		Neurolysis		+
	35	+		Partial resection and suture		+
	36	+		Resection and suture		+ (sensation only)
	37	+		No operation	+	
	38		+	No operation	+	
LATERAL	39	+		Lat neuroma excised	+	
POPLIT-	40		+	No operation	+	
EAL	41	+		No operation—Still a discharging wound	—	
	42	+		Large gap—Opn. impossible	—	
	43	+		Opn.—resection and sut.	+	
	44	+		No operation	+	
	45	+		No operation	+	
	46	+		Opn. excision and sut. Reformation of sut.	—	
	47	+		No follow up	—	
	48	+		No operation	—	
	49	+		Probable recovery		
	50	+		No operation—Still discharging wound	—	
POST	51	+		No operation	—	
TIBIAL	52		+	No operation		+

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CHAPTER 44

TRAUMATIC PARAPLEGIA

PARAPLEGIA is unfortunately not very uncommon as the result of accidents in the civilian community, but war also produces a number due to battle casualties or accident. Compression fractures of the spine are a form of lesion not uncommonly seen as the result of aircraft accident, and concomitant injuries of the spinal cord sometimes occur.

Transverse lesions of the cord are very serious, and the risk to life is still considerable, but the outlook of the paraplegic is much less tragic than formerly. These patients are not necessarily doomed to infection of the urinary tract, and their prospects of acquiring useful function of the lower limbs are often better than once thought possible. Lieut-Colonel J. B. D. Galbraith compiled a brief account of the care and rehabilitation of the paraplegic which was circulated in service hospitals. He estimated that in Australia there were about 50 paraplegics due to war, a small experience compared with the figures of England and America, but demanding early and assiduous attention.

EARLY TREATMENT

If the signs indicate a complete transverse lesion of the cord, any displacement of the spinal column should be reduced if possible, but the risk of further damage makes this inadvisable if the spinal lesion is only partial. Metallic foreign bodies or indriven bone in the spinal canal may warrant laminectomy, but success is not probable.

CARE OF THE BLADDER

Delays in transport and lack of full facilities on some of the long lines of communication have often induced surgeons to perform cystostomy, but unfortunately the sequel of this procedure has only too frequently been gross infection and a contracted bladder. Where skilful care and nursing are available, drainage with intermittent irrigation through an in-dwelling catheter is preferable; tidal drainage is still better. Arrangements for tidal drainage were available in all army hospitals, and there were no difficulties in setting up an extemporised apparatus either to meet an emergency, or, better, in preparation for use in time of need. In a hospital a cystostomy wound could be encouraged to close, the capacity of the bladder stimulated to increase, and efforts made to gain automatic or muscle-controlled emptying. It was rarely that this could not be achieved. An alkaline cystitis was to be avoided at all costs, therefore indiscriminate treatment by sulphonamides was avoided. On occasion prostatic resection was justifiable.

BEDSORES

Unfortunately paraplegic patients reaching base hospitals usually have bedsores, chiefly owing to the drawbacks of immobilisation, which must be maintained to prevent further damage to the spinal cord. A lowered plasma protein level following injury may also be a contributory factor. Bedsores should be treated as a problem of surgery, aiming at the removal of sloughs, preparation of a clean bare area and covering it according to modern methods.

NURSING

One of the greatest problems is that of movement of the patient in bed, in order to encourage healing of bedsores or to prevent their occurrence. Special beds are very helpful, or the use of a plaster shell. Suspension methods may be helpful, but even with the added security of a shell many surgeons prefer to have patients turned at intervals by an expert team of four, and consider that the apparent wastage of manpower in reality saves time and serves efficiency.

EXERCISE

Early physical exercise is a necessity; even spinal instability does not prohibit the exercise of those muscles that are available for use. With complete lesions early movement is imperative, as the development of muscular power in the unaffected areas will be of immense advantage. Free turning and movement in bed are encouraged. Exercise of such abdominal muscles as are active will help bladder control and general movement, and enhance the prospect of walking.

As soon as possible the patient is got out of bed into a wheeled chair, and as quickly as may be put on his feet with the help of iron braces. Regular instruction in progressive movement is essential.

REHABILITATION

The psychological aspect of re-enablement of the paraplegic is vitally important, and with all these measures he has a reasonable chance of physical independence. The man who can walk to any useful degree is in every sense on his feet. Trade education and social measures to establish such men in industry have conferred immeasurable benefits on paraplegics, whose future is now much more hopeful, in spite of the grave nature of their handicap.

CHAPTER 45

WOUNDS OF THE CHEST

IN THE MIDDLE EAST

THE great advances in civilian surgery of the thorax at first suggested the possibility that wounds of that region might be submitted earlier to surgical intervention. Experience, however, dictated conservatism. All war wounds of the chest were treated conservatively unless (1) air was being sucked into the pleural cavity, or (2) a tension pneumothorax existed, or (3) there was an effusion into the pleural cavity.

The best method of closing a sucking wound of the chest has been debated by surgical authorities, but the Australian school of thought was decidedly in favour of suture. This was found to be the only reliable method; particularly where the wounded man faced a journey, occlusive dressings were found unsatisfactory and ineffective. Suture could be done at an aid post, as a rule without anaesthetic, silkworm gut being passed deeply to the ribs at a distance of at least half an inch from the edges of the wound. Difficulty was sometimes found with large wounds, but firm sutures over a pad usually controlled the entrance of air. Occasionally a flap made after the use of a local anaesthetic was needed, pending resuscitation and further measures at an operating centre. Another firm indication was to keep the pleural cavity dry, a practice established in 1918, and too often forgotten since in civil practice. It is also important to be alive to the possible production of a tension pneumothorax, so simply relieved by a needle and tubing under water, yet so drastic in its effects if unrelieved.

The physical signs of thoracic injury were often misleading. A foreign body was often present in the thorax, and this might cause an extravasation within the lung, difficult to distinguish clinically or radiologically. It was important to ascertain if pleural effusion was present, for a rapidly increasing collection of fluid displacing the thoracic viscera might produce symptoms of shock. It was futile to treat these symptoms by conventional general methods when the local cause was simply discovered and removed.

In the desert very few chests became infected, owing in part to the relative sterility of the surroundings, and also to the correct principles followed. Oral administration of sulphonamides probably was of value too in discouraging infection by streptococci.

Littlejohn published the results of 100 cases of penetrating wounds of the chest in Tobruk from April to June 1941. Sucking wounds were always sutured in forward areas except in the earlier months of the siege, when men arrived with them unclosed, often having received multiple wounds. Where simple silkworm gut sutures (not mattress sutures) would not close the opening, a flap would be made under local anaesthesia. These men on arrival were placed in a resuscitation ward and kept warm. Move-

ment was reduced to the minimum. Transfusion was given only if necessary. This coincided with the practice on other fronts when men with recent chest wounds were seldom transfused in main dressing stations. Oxygen was administered with a tube in this unit, since the hazards of shipwreck had ruined the B.L.B. masks in salt water, and Haldane masks were not tolerated by the patients. The injuries were classified according as the patient achieved a physiological balance of pulmonary function. If the lung was wounded, there would be air and blood entering the pleural cavity, but this would cease when the lung collapsed. If balance was struck early and lost later, with increasing dyspnoea and distress, it pointed to a rising intrapleural pressure from exudate, which was causing mediastinal shift and threatened danger. In these circumstances aspiration was imperative. Some men never achieved equilibrium after their initial shock should have passed; this was usually due to bleeding from a systemic artery such as an intercostal or internal mammary, and was an indication for early operation. Pressure pneumothorax occurred in some with a valvular opening in the lung, but it was uncommon.

There were 21 deaths among 100 patients, but only in 7 cases was death due to the chest wound alone. Of 40 sucking wounds 13 were fatal. X-ray examination was used in the diagnosis in most of the patients; it was sometimes possible to leave them resting in the X-ray room under observation. Most of the men were sent out of Tobruk by the tenth day. Further experience convinced Littlejohn of the value of routine aspiration in forward areas.

The disposal of a foreign body in the chest was a matter for considerable debate. On the one hand it seemed wise to send men with foreign bodies lodged in the chest back to Australia for observation or further treatment. On the other hand, realising the dangers of lighting up sepsis at any time round the foreign body, E. S. J. King operated on a number of men in Palestine and removed the foreign body. At the 2/1st Australian General Hospital he saw ninety-six patients in four months with thoracic surgical conditions, twenty of whom had foreign bodies. Twelve of these were operated on with good results, though sharp reactions and rather a stormy convalescence followed in some instances. These men were returned successfully to duty.

The results produced by the foreign body in transit through the pulmonary tissues varied; sometimes only a few adhesions along the line of flight and some local fibrosis were found, or an area of traumatic pneumonitis in which a mild degree of infection might persist for a time, or a small collection of purulent material. Occasionally blood or infected fluid was found shut off within the pleural cavity. Mediastinal approach was made by the most direct standard route. With careful post-operative treatment the results were good. When the operations were carried out in Palestine modern anaesthetic methods were not available. Consequently preoperative pneumothorax was performed if possible to avoid shock from collapse of the lung when the chest was opened. Extemporised apparatus had to be constructed for this purpose. If adhesions were present the lung

was freed enough to allow palpation of the foreign body. Anaesthesia with cyclopropane and controlled respiration was just coming into use at the Heidelberg Hospital in Melbourne when the war ended.

Though there were some individual differences of opinion about the removal of foreign bodies from the chest, there was complete unanimity in the principle that it should never be done except in a well-equipped base unit, and that forward treatment should aim at the closure of sucking wounds, the pleura being kept dry by aspiration and restoring blood loss. Difficulties arose in keeping patients in the half-sitting posture, as ambulance stretchers were not so adapted and some extemporisation was necessary. The same trouble was found later in New Guinea. At Soputa in 1943, for example, a back rest consisting of a wooden framework covered by a blanket was attached to a Stokes litter and proved satisfactory. Another point in posture of patients in transit is the desirability of keeping the damaged side down so as not to impede free movement of the uninjured half of the thorax. On all fronts the methods used and results obtained in chest wounds were similar, with occasional divergences. For instance in later campaigns of the Middle East one unit recorded good recoveries in men treated with transfusion and oxygen with the minimum of interference.

SOUTH-WEST PACIFIC

Though infection was a considerably greater risk in New Guinea than in the Middle East, especially by staphylococci, close observation and adherence to the recognised principles usually ensured good results. Major J. I. Hayward reported from experience in New Guinea that staphylococcal infection almost invariably caused clotting of the blood in traumatic pneumothorax. This could usually be prevented by early aspiration with or without air replacement. The object of air replacement was to prevent re-expansion of the torn lung, with danger of bleeding. This was in any case necessary only for a day or two, after which all fluid and air were removed. At the aid post the rule was to close sucking wounds, to watch the patient carefully and if equilibrium was not attained to perform aspiration. This individual assessment of each man's physiological balance of conditions within his chest was important and enabled him to reach a clearing station or hospital with greater safety. Coagulation of blood in the pleura might be countered by aspiration at a reasonable level, say the seventh interspace, and moderate or stringy deposits of fibrin could thus be withdrawn. A large continuous coagulum could not be aspirated and mechanical breaking-up might be necessary through a thorascope or by thoracotomy. Drainage might also be needed. These problems were simplified by penicillin, as will presently be told.

At a base hospital Major C. H. Horsley collected a series of forty men with gunshot wounds of the chest, admitted over a period of three months. One-quarter of these men with perforating wounds of the chest had a broncho-pleural fistula. This was a common reason for failure of "sucking" wound to close. Control was obtained by a large sponge rubber pad, combined with dependent drainage. Negative pressure drainage was found of

particular value where other methods had failed, and could be terminated when the daily pleural drainage dwindled to half an ounce and the lung was sufficiently expanded to prevent air from entering the pleural cavity. Physical exercises as described below were begun at this stage. Intrapleural foreign bodies were removed, and those in the chest wall, though there was a risk of creating a "sucking" wound. Foreign bodies in the lung were left alone and did not appear to cause trouble. The introduction of penicillin greatly lessened the risk and incidence of pleural infection.

J. I. Hayward found only two patients with infections among twenty-two with haemothorax in the Netherlands East Indies campaigns. All these had prophylactic penicillin, and the infections were due to coliform organisms. Similarly at Aitape in 1945 out of fifty patients treated at the 2/11th Australian General Hospital for haemothorax only three had a complicating empyema, and two of these infections might have been avoided by earlier aspiration. After drainage of a haemothorax the introduction of penicillin into the pleural cavity became standard practice.

Rose and Newson reported thirty-two cases of gunshot wounds of the chest in the South-West Pacific Area. These did not include the usually serious abdomino-thoracic injuries. Fifteen were simple perforating wounds and seventeen patients had wounds requiring excision, seven being sucking wounds. Damage was due to injury by the missile, or by bone fragments, or to concussive effects. Mediastinal emphysema was present in a few instances. Most of the patients reached the operating unit within two to twelve hours; some were treated in a field hospital, others in a forward area where all facilities were available except X-rays.

During the period of initial observation, aspiration was done if necessary and tension pneumothorax relieved by an indwelling needle. Shock was treated by rest and morphine and blood transfusion, if necessary. "Pentothal" was the usual anaesthetic, supplemented by oxygen. After excision of the wound the pleura and lung were inspected, and foreign bodies removed from the pleural cavity. The lung was inflated, the pleura sutured if possible and also the soft tissues. Fifty thousand units of penicillin were left in the pleura and no drainage was used. If thought wise primary skin suture was performed. After operation close watch was kept for signs of increased intrapleural tension. It must be emphasised that all surgeons handling thoracic injuries found that the signs of pleural effusion were often anomalous. A large effusion might "creep up" unawares. On several occasions a large quantity of blood has been detected and removed days after the infliction of the wound. In this series fibrinous clotting was observed a few times, but massive early coagulation was not seen. If infection occurred aspiration and instillation of penicillin were carried out, and thoracotomy performed only if thick pus formed an empyema and the lung would not expand. Penicillin was of course given parenterally as a routine. Two patients of the thirty-two died within a few hours of being examined: of the remaining thirty, twenty-four had blood in the pleural cavity. All the wounds healed successfully and the lungs expanded in six weeks, except in three cases in which broncho-pleural fistulae

occurred. Rose and Newson contrast mortality figures for two wars in thoracic wounds of men surviving long enough to undergo surgical treatment. In the 1914-1918 war the death rate was 24 per cent, whereas in some collected series in the 1939-1945 war the rate was 8 per cent. This is due in part to penicillin, but very largely also due to a keener appreciation of the causes of shock in these injuries, early treatment, in particular early and repeated emptying of the pleural cavity.

PHYSIOTHERAPY

Provision was made for giving special exercises to patients with chest wounds in the Middle East. In the 2/1st Australian General Hospital tents were specially fitted out for this purpose. In other areas also these routines were regarded as essential and the principle was followed of starting physiotherapy as soon as possible. The more severe injuries caused some inhibition of breathing on the affected sides which was greater in proportion as the interval became longer between the receiving of a wound and the starting of special exercises. Major J. I. Hayward described methods similar to those used at the Brompton Hospital and this model was generally followed in the after-treatment of severe traumatic and inflammatory diseases of the lungs, in particular those involving the pleura. The types of abnormal respiration which it was found important to counter were: asymmetrical respiration, due to diminished movement on the affected side; premature inspiration due to incomplete expiration; disproportionate respiration when the diaphragm or part of the thoracic wall was not used in a balanced manner; paradoxical movement of the diaphragm; and abnormal use of the lower abdominal muscles in breathing. The usual exercises prescribed in manuals of physical training are not only without value in the anomalies following injuries of the chest, but may be actually harmful, owing to their encouragement of the upper and front parts of the chest and sometimes improper use of the abdominal muscles.

The most important exercises for regaining proper muscular control are those using the diaphragm and the lateral part of each side of the chest. In addition appropriate exercises can emphasise the breathing of either side of the other portion of the chest or of the posterior part. For this work a skilled physiotherapist was necessary who had been specially trained in the correct methods of overcoming defects in breathing. Exercises were begun when the patient was still confined to bed, at first lasting for only a few minutes, but were conducted in a special department as soon as the patient was up and about. It was found that in some conditions such as those associated with haemothorax, correct exercises should prevent the development of any deformity and by about five weeks after the injury the patient should be ready for a convalescent depot, all blood by this time having been absorbed. Even injuries requiring drainage of the pleural cavity should not keep an otherwise healthy man more than six months away from his unit.

These methods simply applied physiological and anatomical principles and were found, in practice, to give very good results. Such treatment

should prevent largely, if not entirely, distortions of the bony cage of the thorax and deformities of the spine. It is, of course, common knowledge that kyphosis and scoliosis may easily be produced by thoracic injuries which give rise to a diminished volume of one side of the chest. After an empyema there is a tendency to scoliosis of the thoracic spine with the concavity to the side of the lesion, and crowding of the ribs on that side. This deformity would naturally tend to depress the shoulder on that side, but it is usually raised because of a subconscious tendency to try to bring the shoulders to the same level. The discomfort of a drainage tube may also accentuate this distortion. This is one of the many indications of the need for early individual attention.

Though special thoracic surgical work was done in a number of centres, no department as such was ever officially formed, nor was there any formal "establishment". The work done at the 115th Military Hospital at Heidelberg attained the standard of a special unit or department and included an important part of the treatment of patients with tuberculosis at Bonegilla hospital, but was not officially recognised as an independent unit. That the work bore fruit is evident in its continuance by the Repatriation Department in this and other hospitals which later came under its control.

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CHAPTER 46

WOUNDS OF THE ABDOMEN

THE rate of survival after abdominal war wounds was not much improved in the years following 1918. In the Spanish war Jolly recorded a death rate of 50 per cent, and at first sight it would appear that little better was achieved in the 1939-1945 war. The overall recovery rate from abdominal wounds in the Middle East was not better than 50 per cent, though in one series it rose above 70 per cent. In New Guinea the general rate was about 50 per cent, though in some small series it did not exceed one-third recoveries. Such figures are illusory and without consideration of circumstances give no idea of the value of the work done.

The extended use of resuscitation, particularly transfusion of blood, improved the outlook somewhat; so too did the wider application of duodenal drainage. But as in earlier experiences in the field simple methods, deftness in applying appropriate techniques, and speed, both in decision and in operating were important factors. Figures alone do not give an accurate picture of the part played by the surgeon in patients' recovery, for the variable factors such as the time elapsing before surgical aid can be given, the facilities for handling the casualties needing attention, and for securing post-operative care, depend largely on the tactical situation and the nature of the country to be traversed both in front of and behind the operating centre. The problem is always a potentially grave one, for as Gordon-Taylor has well said: "In the abdomen there are no insignificant wounds".

The first Australian experiences in the early desert campaign were limited as regards abdominal surgery, but they followed along the lines expected. The nature of the visceral damage was often unpredictable. The surgeon who carried the responsibility of *triage* or selection of patients suitable for operation and the priority of their claims was guided by the usual signs of an abdominal emergency, such as the facial expression, rigidity of muscles, pain and tenderness, vomiting, and a rising pulse rate. Loss of blood, overt or concealed, modified this picture according to the degree of shock present. The wound of entry was not always helpful in the making of a decision, as of course it was often not in the abdominal wall or in the back, but in the thorax or even the buttock. Sometimes laparotomy only could settle the diagnosis. The frequency with which intra-abdominal blood vessels were damaged usually made blood replacement necessary. Experience showed too that death could occur from internal bleeding during what might otherwise have been the recovery period. There were, of course, as was only too often found in the 1914-1918 war, men whose abdominal wounds were too grave for surgery. A realistic view was necessary with these patients for whom morphine alone remained. Damage of intestine was common, and in general, abdominal wounds involving hollow viscera were much more dangerous than

others. Repair or resection of damaged bowel was carried out according to the indications. Usually there was not time for elaborate techniques. On occasion good results followed when anastomoses were performed with only a single line of suture. Wounds of the colon had a high mortality, though the outlook was somewhat improved later when exteriorisation was practised. Drainage of the abdominal cavity depended, as usual, on judgment: it was not found as important as once thought.

C. A. M. Renou in 1942 recorded the results in the case of 72 patients with abdominal wounds treated at a forward operating centre. All patients were screened in the X-ray room in the presence of the surgeon. This could usually be done on the way from the resuscitation ward to the theatre. Foreign bodies were located and marked. Even in this small series the seriousness of wounds of hollow viscera is evident; 8 out of 9 men died with wounds of the stomach, 20 out of 29 with wounds of the small intestine, and 15 out of 25 with wounds of the colon. Many of these wounds were of course of complicated type, involving other structures.

The influence of favourable factors additional to competent surgery is emphasised in a series published by T. Giblin, setting forth the results of abdominal operations on 90 men at a field ambulance. The conditions here at Alamein were favourable; accommodation though in tents was good, the warfare was static, and a casualty clearing station within four hours' journey. The team had the advantage of using special stainless steel theatre furniture designed by Lieut-Colonel F. J. Clark for a mobile surgical team and presented by the Australian Red Cross Society. Patients were held at least seven days before being sent to the clearing station. The usual routines of transfusion and post-operative gastric suction were followed, and the daily output of urine was watched, fluid being given intravenously until it reached a litre. During a period when all these routines attained a high degree of efficiency the recovery rate rose as high as 72 per cent. This exceptional rate was held over a small series only. On the whole the recovery rate after abdominal wounds in the Middle East was not better than 50 per cent. The lesson to be learned, however, is that the recovery rate can be improved if the surgeon has the advantages of prompt reception of patients, good operating facilities, bed accommodation for an adequate period of after treatment, and smooth transport to a base hospital.

Ileus was not an uncommon complication in abdominal injuries. A tube for duodenal drainage of the Ryle type was used, but the demand made it necessary to extemporise. E. S. J. King earlier recorded that his own surgical team and another independently devised a tube made from a perforated cartridge case. Giblin's figures showed that men who recovered and were ultimately sent on to the base averaged 9 hours from their first aid treatment in an aid post, whereas those whose transit had averaged 13 hours in duration died. Ten hours appeared to be the critical period: after this the results deteriorated greatly. The general condition of patients of course was an important factor in all abdominal work. Severe shock meant delay and resuscitation to a point where operation was practicable:

this in its turn depended on the severity of the wound. The anaesthetic used for most abdominal wounds was "open" ether.

The influence of sulphonamides was hard to assess. In this Alamein series a suspension of sulphadiazine (10 grammes in 100 c.cm.) was available from the R.A.M.C. transfusion unit, and this was thought to be of definite value where the bowel was injured. It was introduced at intervals for two or three days through a small drainage tube.

Unexplained deaths sometimes occurred from abdominal injuries. An increasing pulse rate after twelve hours or more was a warning sign, even when there was no indication of peritonitis or ileus. This phenomenon is somewhat reminiscent of those patients with thoracic injuries who do not achieve equilibrium; though the mechanical factors of the chest wounds are here not present there is always the possibility of concealed bleeding. Death after a latent period of days might also be due to ischaemic renal necrosis.

In Tobruk at the 2/4th Australian General Hospital where emergency surgery could be performed under conditions of reasonable deliberation it was thought that a neuro-vascular reflex might be responsible for producing shock associated with blood concentration. This is mentioned in the section on shock, but it cannot be said that any such factor of importance has been clearly established. It was noticeable, however, that as experience of surgeons in abdominal war wounds grew the extreme value of early resuscitation by blood or serum replacement became even more highly esteemed. An officer was assigned to the work of resuscitation in surgical teams and patients being so treated were carefully watched by him and by the surgeon. In 1942 a more rapid rate of blood flow than that previously practised was found practicable and desirable: 500 cubic centimetres of serum were given in the first five to ten minutes, instead of at the more usual rate of a pint in thirty to forty minutes. If the patient was not very exsanguined another 500 c.cm. of serum were given, followed by blood at the rate of a pint in ten minutes or less for the first two pints. This method generally secured a rise of blood pressure to the desired safe standard minimum of 100 millimetres of mercury in one and a half hours. Reactions were rare and appeared to be due to causes other than too rapid a rate, as they ceased when another blood was substituted.

In New Guinea the conditions were very different. During the first campaign fought over the Owen Stanley Ranges to the coast the results were good considering the difficulties, especially on the flat muddy country near the north coast. The recovery rate here averaged nearly 50 per cent. Air evacuation, previously impossible, was later practicable. Resuscitation was by wet serum, blood from local donors, and followed by glucose and saline. Malaria was so prevalent that all sick and wounded were given 30 grains of quinine per day as a routine. Only a few abdominal wounds were treated by surgical teams at Myola and Wau; few men survived the difficult conditions. In the later Salamaua campaign abdominal injuries, though few in number, again carried a serious prognosis. Here and following the Lae landing, that is, in the 1943-1944 period, the survival rate

was about 33 per cent. The adverse factors here were the delays before patients reached an operating unit, due to the nature of the country, the trying climate, the lowering of patients' resistance by malaria, the limitations in supplies of blood, and the scarcity of sulphadiazine. Of these factors the first was of prime importance. In spite of the drawbacks alleged to exist in the use of barbiturates for patients with abdominal wounds, "Pentothal" was used with success in these campaigns. Good relaxation was obtained and little trouble encountered.

The introduction of penicillin improved the outlook in abdominal injuries. At Aitape, for example, in one small series of men with 15 abdominal wounds only one death occurred and that from multiple injuries.

During the actions on Borneo the moderate resistance offered by the enemy lowered the surgical casualty rate and facilities for early treatment were good.

Throughout all the campaigns certain principles familiar in the treatment of abdominal war wounds were emphasised. As already pointed out, all abdominal wounds are potentially serious, but provided the wounded man can survive the immediate hazards of the days following operation he has a good chance of making a full recovery. At the moment of wounding his prospect depends on the intrinsic seriousness of his wound, and the difficulty of transporting him to a surgical unit. His wound will vary in seriousness according to the amount of bleeding or soiling of the peritoneum, the degree of damage to solid and hollow viscera and the involvement of other parts. These elements of danger depend to a considerable extent on the nature and velocity of the missile. A nearly spent fragment of shell is much more disruptive than a high velocity bullet. The amount of intra-abdominal bleeding is important, as the need for its control and for replacement of blood depends on the factor of time.

Wounds of the colon carry a greater risk of widespread peritoneal infection: colostomy or the exteriorisation of the colon has lessened this somewhat. Diversion of the colon's contents from the vulnerable peritoneum and the local or parenteral use of sulphadiazine or similar sulphonamide drug and in later years the use of penicillin have materially increased the chance of recovery.

Thoraco-abdominal wounds deserve special mention. The least serious may involve the chest only as a port of entry of a missile: the most serious may cause extensive damage of organs in both body cavities. Such a wound may be predominantly thoracic, and it may be possible to deal with abdominal damage from the thoracic aspect. Separate access to the abdomen may be necessary to deal with wounds of greater gravity.

The importance of the time elapsing between first aid and efficient resuscitation for humoral shock has already been stressed. The longer the delay in effecting repair and stopping bleeding, the worse the prognosis. This in turn depends largely on the nature of the terrain and the distance of the surgical post from the place of wounding, which is usually the front line, if such has geographic existence. Such a distance must in any case be reckoned in hours and not in miles. Another danger arising from

the terrain itself is that of infection: it was found that in abdominal wounds, as in others, the hazard was less in the dusty but relatively clean desert air than in the contaminated soil of banana groves in Syria or the muddy coastal plains in New Guinea with their risk of anaerobic infection.

After operation the wounded man has to face the risks of peritonitis, now considerably lowered by sulphonamides and penicillin, and of ileus. The use of the Miller-Abbott tube and its variants has lessened the risk of the latter.

Extemporised fittings can carry out the function of drainage of the duodenum or jejunum very well. Indeed a "Soluvac" set was successfully adapted for this purpose, using a 3-16th inch rubber drainage tube with a blocked end and lateral holes. Through this, continuous infusion of fluids could be maintained, especially in all patients with a ruptured viscus. Salt requirements could simply be met by using either 5 per cent glucose in water or normal saline solution according to indications to preserve the electrolyte balance. The excretion of a litre of urine in twenty-four hours was a fair indication of equilibrium. Fluid balance charts were kept to check intake and output.

These technical procedures are within the reach of orderlies with some training: some of these men attained high degrees of skill, though much more personal supervision of sick men by surgeons was necessary than when trained nurses were available. In the forward units female nurses were not to hand, but the advantages of their care and influence were obvious in clearing stations and hospitals where they were stationed. The work involved in maintaining correct posture, checking and maintaining fluid balance and the ordered flow of fluid through a tube, which perversely blocks at busy times in a ward, is no light matter. If equilibrium in fluid balance is not gained there is too the risk of anuria even with abdominal wounds in which the renal tract is not known to be damaged. This is all the more important as prompt recognition and treatment are imperative if the patient is to have a good chance of recovery.

The need for keeping men for a week at least after operation caused deep concern in some areas. Where an operating unit was semi-stationary, arrangements for holding men during the anxious first post-operative days could be made without embarrassment, but one critically injured man could hold up a unit. In the first desert campaign a loose union of two field ambulances solved this problem temporarily, as parts of the unit could perform the "leap-frog" manoeuvre. But it was obvious that in highly mobile warfare an independent forward unit would be needed, as even when air transport was possible it could not follow up the operating teams. The position was different in jungle fighting: there transport by land was equally difficult, though for different reasons, but high mobility of units was not needed nor indeed was it usually possible. These questions are largely administrative, but they have so much bearing on certain types of war wounds that they are stated here.

Even after a wounded man had been promptly brought to the surgeon, promptly dealt with and held under observation for a safe period, pre-

ferably a week, he still needed smooth and appropriate transport to a base area. During this last journey it was usually desirable that the Fowler position adopted during his post-operative period, should be maintained. Patients carried in ambulances in the semi-sitting posture travelled much better than when carried lying flat. The adoption of this position in an ambulance robbed the vehicle of one stretcher space. In an aircraft this mattered little: it was the ideal method of travel for wounded men.

Though the mortality of abdominal wounds is high, experience has shown that attention to every relevant factor can lower the death rate. Recognition that some of the causes of death are often preventible, such as ileus and haemorrhage, has been a stimulus in a field in which greater advances have been made than mass statistics show. Finally, even granted the most favourable conditions, great balance and judgment are required. Forlorn chances among dying men cannot prejudice the recovery of those waiting, but no man can be allowed to run unnecessary risks for the want of a little extra time and care in exploration.

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CHAPTER 47

WOUNDS OF BLOOD VESSELS

INJURIES of large blood vessels were not infrequent. Unfortunately some of these were rapidly fatal before surgical assistance was possible. Occasionally the anatomical nature of a wound was such that a man could reach a surgeon in time for a damaged artery to be secured. One such case was seen in the 2/4th Australian General Hospital during the siege of Tobruk. Such blood loss had occurred from the femoral artery that respiration stopped and the feebly beating heart had a rate of only about 20 per minute. After three pints of blood had been quickly given bleeding began again, but the surgeon was then able to secure the vessels without an anaesthetic, and the patient eventually recovered.

Serious damage of blood vessels was sometimes inflicted by the ballistic effect of a missile which passed close to them without actual impact. Such wounds needed careful anatomical consideration by the surgeon. Remote ballistic effects of missiles sometimes produced the sequel of arterio-venous aneurysm, which became apparent later and required surgical intervention.

Owing to the constant additional burden such a vascular communication imposes on the circulation, hypertension and cardiac failure will occur unless the opening is closed. The radical measures necessary to do this are well known, the ideal being ligation above and below the aneurysm and removal of the affected parts of the artery and vein. In a limb already the subject of vascular injury this is often a major undertaking. Sometimes risks had to be taken. For example in the hospital in Tanjong Priok prisoners' camp in Java, Captain Poidevin successfully operated in an extemporised theatre on a brachial aneurysm. The sac could not be safely removed, and ligation above and below was performed. Simple aneurysms of an artery occur also, usually appearing after some time as the weakened arterial wall gives way, or when effused blood is absorbed and shrinkage of tissue permits the pulsation of the vascular swelling to be obvious. Injuries of nerves in the associated leashes may complicate the vascular damage.

The early management of gunshot wounds endangering or injuring arteries therefore was important in forward surgical centres. Major D. Leslie in a description of these pointed out the importance of spasm, evidences of which were often seen. A near miss could set up spasm, so too could partial division or even complete division of an artery. This was sometimes a protective mechanism, and prevented more serious loss of blood. In one instance spasm of the anterior and posterior tibial arteries was observed after traumatic clotting in the peroneal artery: this was immediately relieved when the damaged artery was tied. In partial division of arteries the usual sequels were pressure from extra-vascular haemorrhage, intra-articular clotting, and arterial spasm. The risks of secondary haemorrhage and of later formation of an arterial or arterio-venous

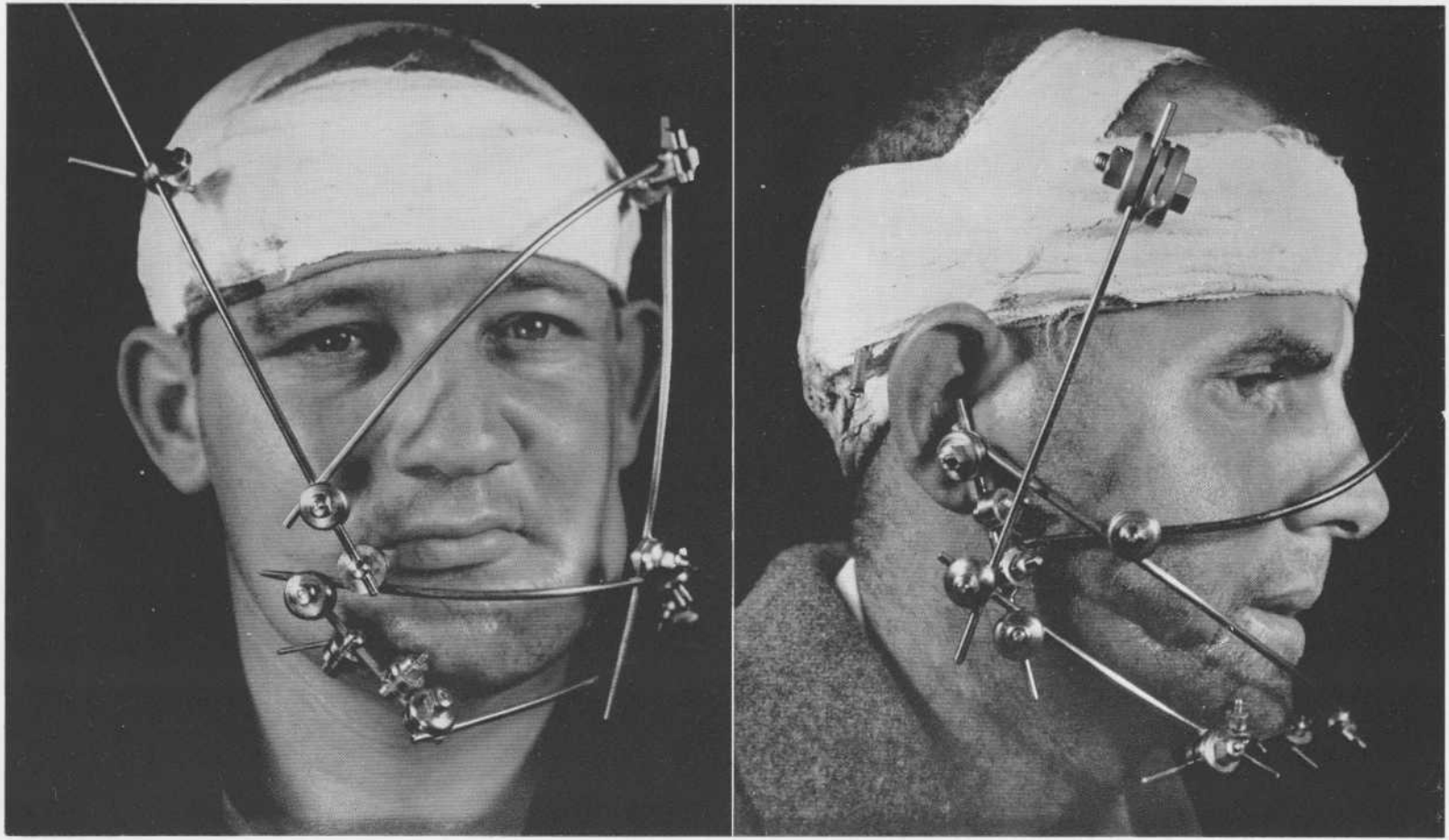
aneurysm were always to be considered. In complete severance of an artery, though spasm might seal the site of division, bleeding might occur from the distal end of the vessel: this is a good sign, indicating a functional collateral circulation. In the handling of these injuries blood transfusion was often necessary after the bleeding point had been secured. When a large vessel had been damaged examination might reveal an artery bleeding in the wound, a vessel exposed in the wound, but not bleeding, or evidences of impaired circulation in a limb in which there was a small wound. Where the artery was bleeding the issue was clear, both ends of the vessel should be ligated, and if the vessel was only partially severed it should be divided completely and both ends tied. This procedure was less provocative of spasm then simple double ligature without division. When an artery was exposed in the wound, damage to its wall, such as contusion was rightly regarded as evidence of possible damage especially rupture of the intima, and ligature was indicated. When the vessel appeared to be intact the surgeon was guided by judgment in each individual case.

The issue is not so clear where there is a small wound which has not caused overt vascular injury, but where the circulation in the limb is impaired. Leslie expresses the opinion that in the circumstances under which forward teams usually worked in New Guinea it was wrong to be conservative. If such a patient was sent on, he might have an ischaemic limb by the time he reached the next stage. Therefore he advised excision of the wound so as to decompress vessels possibly damaged; exploration would thus permit ligation if necessary. A small wound not associated with circulatory disturbance did not warrant any drastic action, but if near blood vessels, cautious observation was advisable. A further problem arose where a sound vessel was exposed in a septic wound. Here too each case had to be dealt with on its own merits. Remembering that death has occurred from vascular causes in septic wounds, the question of ligation might arise: if this was thought necessary penicillin would lessen the risk.

Certain other problems remain to be mentioned. A tight calf in a wounded lower limb was an indication for exploration in the popliteal region. In wounds of the hand and of the buttock it was sometimes found necessary to relieve tension and take other necessary action. Sometimes of course a vessel could not be secured in the wound, and distant ligature was then the alternative. In head wounds it was occasionally necessary to arrest bleeding from cortical vessels before the patient was sent to a neurosurgeon. This could be done by cautery sometimes, but clips were found a very valuable addition to the forward equipment.

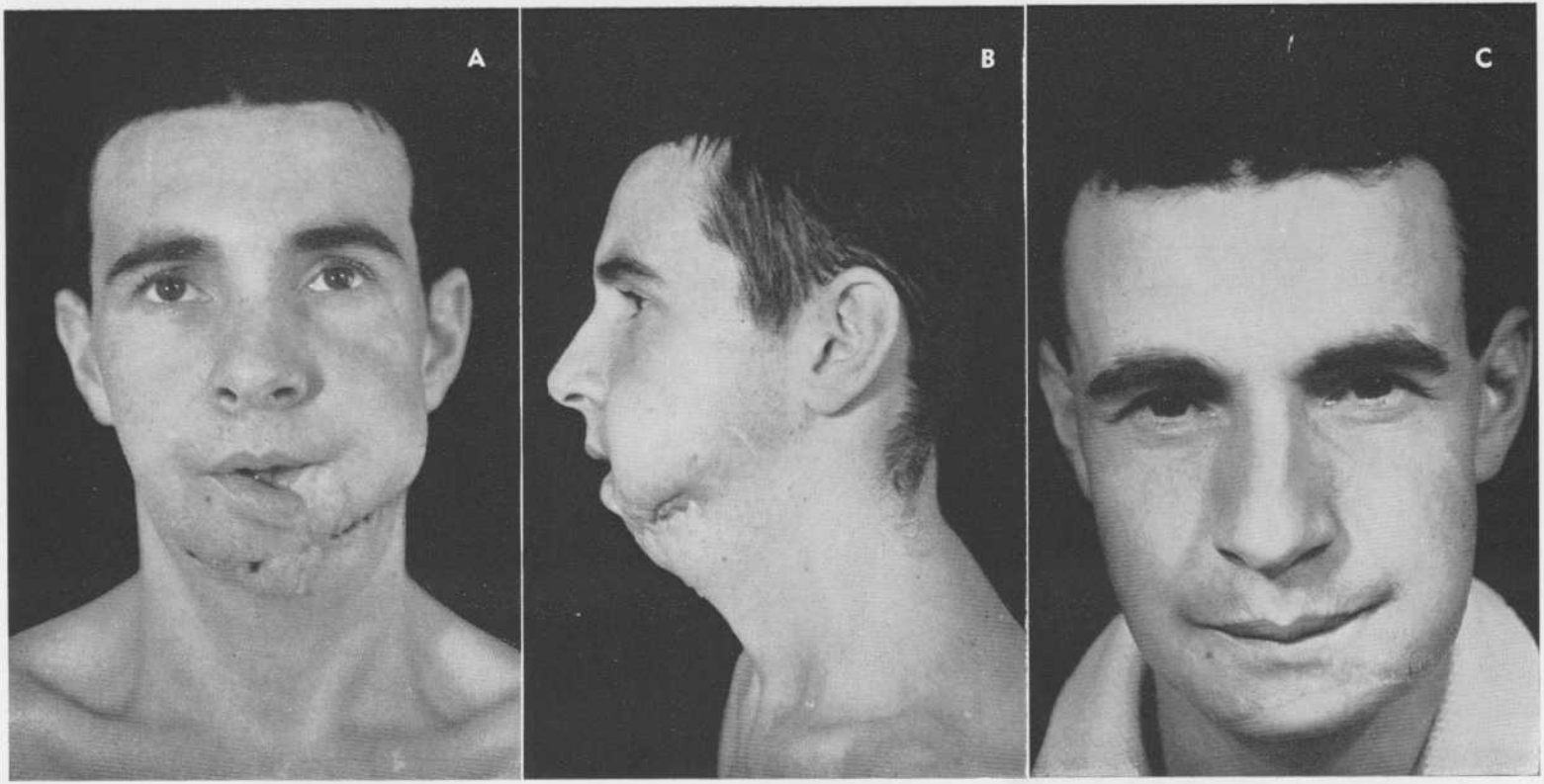
The prime indications in injuries involving blood vessels were to control bleeding, and to help the collateral circulation by removing such barriers as external pressure and vascular spasm. In New Guinea the use of a tourniquet was fraught with some danger when patients had to be carried by native bearers over a difficult route: for this reason it was only occasionally employed.

Major Brooke Moore reported details of thirteen men with traumatic lesions of the great blood vessels. These men were seen among 3,000



Skeletal fixation system used in fixation of jaw fragments—frequently used in association with bone grafting operations for destructive wounds of the face where other forms of fixation were not applicable.

(B. K. Rank)



(B. K. Rank)

Gunshot wound with extensive loss of mandible and chin. Before and after plastic repair—including soft tissue repair and bone graft in jaw.

admissions, nearly all for wounds, to the 2/5th Australian General Hospital when at the Piraeus in Greece after the unit had been captured by the invading German force. This proportion of vascular injuries must be rare: Brooke Moore relates that Professor Pfeiffer, the German consulting surgeon, had never seen so many before. Swelling, thrill or bruit, was present in 12 out of 13 cases. Nine patients were operated on with one death due to sepsis and gangrene associated with a high femoral aneurysm. The operations performed included ligation of the external iliac vessel, common femoral vessels, popliteal artery and vein, and axillary vessels. Direct approach to the injured segment of artery was limited greatly in its application by adhesions and by the finding that these wounds, though not others over damaged vessels, tended to suppurate. Therefore it was thought wise to keep these wounds under observation in case of recurrence and to defer operation as long as possible in order to avoid sepsis. The risk of tying the popliteal artery was recognised in this series and has been emphasised by a number of surgeons in other places, owing to the liability of damage to the collateral circulation of this vessel. Surgical teams have appreciated this risk in treating wounds involving the blood supply of the lower extremity.

Though major advances have been made in some branches of vascular surgery, the expectations of those hoping for the application of new methods to military surgery have not been fulfilled. Though vitallium tubes and venous grafts appeared promising in arterial repairs, particularly with the help of the modern anti-coagulants like heparin, not much progress has been made as yet. Victor Hurley in discussing modern techniques of repairing blood vessels, stated that the most practical method of dealing with arterial wounds was ligature. As most of the patients treated in the Services were young and vigorous, this was more likely to be successful; especially if the metabolism of the limb was restricted by rest and the application of cold. Hurley pointed out too the possibilities of Allen's refrigeration method, in which a tourniquet was used and the limb packed in ice. There is a definite risk of infection in a part whose resistance is lowered by ischaemia, especially as gas-forming organisms may remain viable in ice.

Progress in this field has been made during the war period in the employment of measures designed to encourage collateral circulation in limbs whose arterial supply is precarious. Some aspects of this have already been discussed. Ligation of the main vein is still practised, mainly on the basis of statistical evidence collected by Makin in the 1914-1918 war; its value is not yet clear. The simple method of heating the contralateral limb has been found of value by Australian surgeons. Developments since the end of the war have greatly widened the scope of vascular surgery, but these cannot be pursued here.

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CHAPTER 48

PLASTIC AND FACIO-MAXILLARY SURGERY

AT the beginning of the war preliminary plans were made by Major-General R. M. Downes, the Director-General of Medical Services, Australian Military Forces, for the establishment of facilities for facio-maxillary and other branches of reconstructive surgery. Sir Thomas Dunhill, who was the Consultant Surgeon of the A.I.F. in London, and was active in supplying recent information to the Australian medical headquarters, gave great assistance in these developments by advice and by helping Australian surgeons to obtain the requisite training in England. The details of the development and organisation of plastic surgery in the Australian Army Medical Corps are told in another volume. It is sufficient here to touch on such aspects as outline the history of this special work in service hospitals and indicate its influence on war surgery.

The special hospital at Sidcup established in England during the 1914-1918 war, made it possible for Australian surgeons to attend their own casualties. In 1939, no special hospital existed in England, but arrangements for this highly important work were included in the Emergency Medical Service. Helped by the skilled advice of Sir Harold Gillies as Consultant-Adviser, special units were formed. The title "facio-maxillary" or "maxillo-facial" was soon outworn, as this covered only some 30 per cent of modern plastic repair work in war. At these special units several Australian surgeons, D. Officer Brown, B. K. Rank, and K. W. Starr were trained, and A. J. Arnott as dental surgeon. The work done by these and other Australian surgeons working in plastic units in the Australian Army Medical Corps as they became established thus reflected the principles and methods of British surgeons.

A special facio-maxillary and plastic unit was formed and incorporated in the surgical division of the 2/2nd Australian General Hospital centrally located at Kantara. This serviced the A.I.F. in the Middle East until the end of 1941, and by periodic attachment of medical officers and nurses, some familiarity with plastic procedures was diffused. When the 9th Division remained in the Middle East after the return of the 6th and 7th Divisions to Australia Major D. Officer Brown had charge of plastic surgery in respect of Australian troops and worked with the No. 1 British Plastic Surgery Unit for ten months. This unit, strategically placed at Alexandria, dealt with the considerable work arising out of the Alamein campaign. Later in Australia more units were formed, and ample provision made for the needs of the various Australian States during and after the war. Personal contact of general and dental surgeons with these units, and demonstrations of work and methods spread interest and understanding in the particular problems of plastic surgery through all the services. This ensured that a long range view was taken of the treatment of the many varieties of wounds which require application of the principles of repara-

tive surgery. At the end of the war almost the only men still requiring attention for facial mutilations were among the repatriated prisoners of war. This prompt meeting of demands was due to efficient increase of the organisation of plastic surgery in Australia, and also to the development and close study of the application of modern antiseptics and antibiotics to reparative surgery. This work has reflected on the outlook of other branches of surgery in numbers of ways. Its teaching function has been active and important, and hardly less has been the example of its necessarily meticulous and detailed records, by which the progress of the art and science of plastic surgery can be measured.

FACIO-MAXILLARY SURGERY

The initial technical instruction issued to medical officers in the Middle East laid down that coapting sutures should be inserted if necessary, to prevent retraction of soft parts, but that they should be very few. Fractures of the jaw were fixed by dentures or interdental wiring, with the help of a dental officer if available. Care was taken to leave enough room for the ejection of vomitus. This precaution was especially necessary when men with these injuries were sent from Tobruk to Alexandria on naval ships. Conservation in the trimming or excision of damaged tissue was emphasised.

Further detailed instructions were issued later, designed to give guidance along the most helpful lines of early treatment. In advanced operating units the anaesthetist, surgeon and dental surgeon could cooperate. In the later years of the war dental surgeons under the modified organisation of the newly-formed Dental Corps were not specially attached to field ambulances, but were available in other field units. The special points advised for the avoidance of delay in providing the necessary immobilisation, excision or *débridement* of the wound and drainage were stated in the Middle East Technical Instruction No. 24 (appendix).

All medical officers did not find the barrel bandage a success, and some preferred to use a rubber sheet under the jaw, moored to a headcap. Major D. Leslie found that a broad rubber or linen bandage was very effective when attached on each side to the framework removed from a steel helmet. This framework made a good close fitting cap, and variation of the point of attachment controlled the amount of pull on the mandible. At base hospitals these injuries were often treated successfully with pins inserted in the bones and controlled by adjustable metal connections. Dental surgeons played a leading part in the various mechanical manoeuvres by which a patient with fractured mandible or maxilla could gain comfort and keep his injury immobilised while still able to take food and maintain nutrition.

The care of eye sockets after excision for wounds and other reasons concerned not only ophthalmologists and plastic surgeons, but also all medical officers in surgical wards. Where the retention of a temporary prosthesis required special mechanism the problem was one for a plastic unit.

The technical procedures necessary for extensive reconstructive surgery of the face and jaws cannot be described here as they are highly specialised and not only involve the various methods of transfer of tissues from often distant parts, but also accurate study of anatomical detail.

There are however some basic considerations relating particularly to facial injuries. One of these is the dual need for restoration of a facial mask with its underlying bony structure that will be functional, and at the time aesthetically acceptable. On the fulfilling of these requirements depends to a great extent the ability of a man or woman to face the world and follow a normal life. Without this power there is a certainty that temperament will be altered. Cases occur such as that described by B. K. Rank and H. R. Cash in which a soldier who had suffered a destructive gunshot wound of the face and as a consequence had a severe psychiatric disturbance. His paranoid outlook was so abnormal that he was judged to be psychotic, but once reconstruction of the face and jaw were begun his condition improved, and with attainment of a normal appearance his mental state likewise became normal. In attempting such restorations the plastic surgeon and the dental surgeon approached the problem jointly, and the plans thus made together were followed or modified with complete mutual understanding of the difficulties ahead. In face and jaw injuries immobilisation was an important end, either in control of fractures or of inlay grafts or in maintenance in position of special splints. Unnecessary manipulation must be avoided, and the responsibility for this attainment and control of movable parts was often that of the dental surgeon. Fixation had to be unequivocal in this work, and by the use of metal splints with attachments for firm locking of the jaws this could be attained. His help was also invaluable in ensuring simplicity of design in prosthetic appliances, particularly if removable. Though a certain degree of standardisation was desirable this was never sacrificed to the individual requirements of a particular case, and no trouble was spared in order to serve efficiency. Saving of time, though not a necessary end of plastic work, was desirable also if it could be achieved without loss. In jaw injuries the plastic surgeon had sometimes to disregard the claims of individual teeth or even the line of teeth in relation to the line of fracture, having in mind the hazard of the general surgical condition present. The degree of separation of fragments also had to be decided by the surgeon, who if necessary could supply epithelial inlays and transplant soft tissue from the neck so as to provide for a future bone graft. The dental surgeon modified the technique of taking impressions to suit the conditions, generally using small amounts of plaster and thus avoiding discomfort to the patient.

Most fixation procedures could be done without an anaesthetic, or with local injection or block, but "Pentothal" could be used if the necessary precaution of intratracheal intubation was taken.

For fixation of fragments of a fractured edentulous mandible, extra-oral methods were sometimes used when intra-oral methods were unsatisfactory. This was apt to occur with displacements of the posterior fragment against the tuberosity of the maxilla. This method gave very good results

in chosen cases. Pins divergently drilled into the fragments through stab incisions were connected to T-pieces with universal joints and thus to traction bars which could be tightened to produce the desired tension. In order to avoid the necessity for such methods the desirability of leaving at least one sound tooth in mandibular fragments was advised. Similar devices were employed for maxillary fractures, supported by a head cap of plaster. One of the minor instances of useful devices provided by dental surgeons might be more widely used in civil practice, that is, prostheses for facial paralysis to maintain the lip muscles in normal position.

Surgeons responsible for dealing with injuries received by pilots of aircraft were specially concerned with facial trauma as this was unfortunately often the result of air accidents. Though improved protection was given to pilots in this regard by altered design of the cockpits of aircraft, injuries involving facial bones were not uncommon and called for prompt corrective treatment. The principles adopted in Australian service hospitals were those laid down by British plastic surgeons, under whom the Australian surgeons were chiefly trained. B. K. Rank in a lecture to air force medical officers in September 1942 emphasised the importance of the early adoption of special measures based on the teaching of A. H. McIndoe, Consulting Plastic Surgeon to the Royal Air Force.

One of the most important points was to remove any lingering idea that plastic surgery of the face was a remote repair which could be deferred till later. The facial skeleton, though strong and well reinforced in its upper parts, has components in its middle section which are more fragile and which may readily be impacted into the deeper bony structures. The excellent blood supply of the face, though a powerful and trustworthy ally in repair of the soft parts, here could introduce a disconcerting factor, as organisation of effused blood and compressed soft tissues could so fix skeletal elements as to make subsequent reduction difficult or impossible. Functional derangements such as nasal blocking, orbital distortion with ocular disturbances like diplopia, and dental malocclusion are likewise serious matters, causing both physical and mental trials and demand early recognition. This is not as simple as might appear, as swelling and haematoma formation complicate early diagnosis unless careful palpation and other examination are carried out. McIndoe's classification of fractures of facial bones was found valuable, and shed light on treatment. This recognises (a) fractures due to frontal violence, which may be subdivided into three degrees according to the severity of the lesion, (b) fractures due to lateral violence to the malar and maxillary regions, and (c) combinations of both. Frontal fractures may involve the nasal bony structures, or in addition the maxilla, extending into the orbit, or, with deeper trauma, added fracture of the base of the skull or its anterior fossa. Careful clinical examination could reveal both the simpler and severer grades of frontal and lateral fractures even without the undoubted aid of X-rays. The ideal time for first treatment was fixed at two weeks, after this if contraindications had existed for earlier treatment, such as head injuries, treatment could be undertaken up to three months. After three months mal-unions

could not be reduced, and plastic substitution or camouflage alone were available.

Anaesthesia was often a difficulty, especially during the early stages of swelling, but oedema was not a contraindication either to bony reduction or to the administration of a general anaesthetic. For short procedures, like reducing malar fractures, "Pentothal" was appropriate, provided care was taken to maintain a clear airway. For other injuries it was necessary to pack off the pharynx and give an endotracheal anaesthetic, either by machine if available, or if not, by the simple Flagg's can.

The details of bony splinting and control where these were necessary need not be recounted here. The usual principle of supplying support to structures needing it and applying it from the correct aspect were followed. In the majority of these injuries early cooperation of a dental officer was essential. Even repair of soft parts could not be properly carried out until the question of special appliances and the taking of impressions had been discussed. As in fractures of the mandible full advantage had to be taken of parts or structures which afforded support and anchorage, whether by wiring or splinting teeth, by using external pinning, or by providing a fixed point such as a plaster cap on the head.

These injuries provided facio-maxillary surgeons with opportunities of altering not only an injured man's face but his life to an appreciable extent, and the early cooperation of all medical officers in securing treatment at the right stage was sought and freely given.

Other plastic procedures which were of great importance but belonged to the category of delayed surgery were those carried out on soft tissues scarred or destroyed by extensive injuries and those involving peripheral nerves.

SOFT TISSUE REPAIRS

The earlier stages of treatment of soft tissue wounds have been described elsewhere, together with the improvements made, especially after the introduction of penicillin. The importance of a reparative outlook by all surgeons carrying out war surgery was more and more recognised as time went on. Plastic surgeons in particular emphasised that their specialty was only a delimited specialty where it concerned the more difficult problems requiring equipment and experience of particular kind. The ideal was a diffusion of the principles of plastic surgery; this was well attained among surgeons in the services partly through their opportunities for working over widely scattered fields, but chiefly through their own interest and resource.

B. K. Rank in an article on this subject traversed applications of the simpler principles, such as atraumatic technique, the repair of skin loss without tension, and the grafting of wounds with skin. Primary grafting can be undertaken under conditions in which primary suture is indicated. The indications are the existence of a wound actually or potentially surgically clean, trauma such as that due to deep electrical or chemical burns suited to primary excision, and the various procedures designed to repair loss of skin. Secondary grafting finds an important indication in wounds

which otherwise would heal by slow granulation and epithelialisation, with its inevitable sequel of scarring. Preparation for this procedure include the attainment of good physical form, and the provision of a clean healthy flat surface, with no residual focus of chronic infection. The selection of the method of skin grafting to be employed is important. The dependence of "taking" of grafts on the nutriment, tension and pressure in their new environment is concerned largely too with the thickness of the graft, and as with all plastic procedures attention to detail is essential. The various techniques are dealt with later.

TISSUE LOSS

The replacement of lost tissue has been in the past endangered by lack of capillary haemostasis and the incidence of infection. Plastic surgical procedures have helped to overcome difficulties of haemostasis by the clinical application of fibrin. The first applications of this method were to skin grafting, and the use of group plasma as a source of fibrinogen which can be precipitated by thrombin or thrombokinase has been found valuable. In other surgical fields fibrin mesh has been used widely, and the certainty of "take" in reconstructive operations has thereby been increased. Reinforced by chemotherapy this method has helped to remove some of the delays and disappointments of plastic procedures. The details of reparative manoeuvres cannot be dealt with here, but their scope as applied to the work of plastic surgical units during the war years may be noted.

Grafts of deep structures need protection which can be afforded by covering them by healthy skin and subcutaneous tissue. The greater possibilities opened up in such work has renewed interest in the local and remote methods of combined skin and fat replacement. If anatomical considerations permit, this may be done by local rotation or transposition flaps; if not, remote flaps may often be brought directly to the site required by apposition of a mobile donor site on a limb. If neither of these manoeuvres is practicable a tube pedicle graft may be brought from a remote site; this requires care and patience on the part of the surgeon and considerable fortitude on the part of the patient. D. Officer Brown emphasised the importance of an appreciation of the value of the cross leg flap in repair of deep leg injuries, and described a new technique in plaster fixation and general procedure, which greatly increased the scope and value of this method of repair. The use of open abdominal flaps in the repair of forearm and hand injuries has also been discussed in detail. The cross leg principle was later applied extensively not only in battle wounds and injuries, but in the definite repair of the serious conditions arising from tropical ulcers in the legs of men who had been prisoners of war in Japanese hands.

Defects of contour may now be filled by cartilage or bone grafts. Cadaveric cartilage grafts cut into small quarter-inch or half-inch blocks may be preserved in "Merthiolate", or autogenous grafts may be used. Both have given excellent results in the restitution and modelling of small defects. Larger defects may be filled by cancellous bone grafts from the

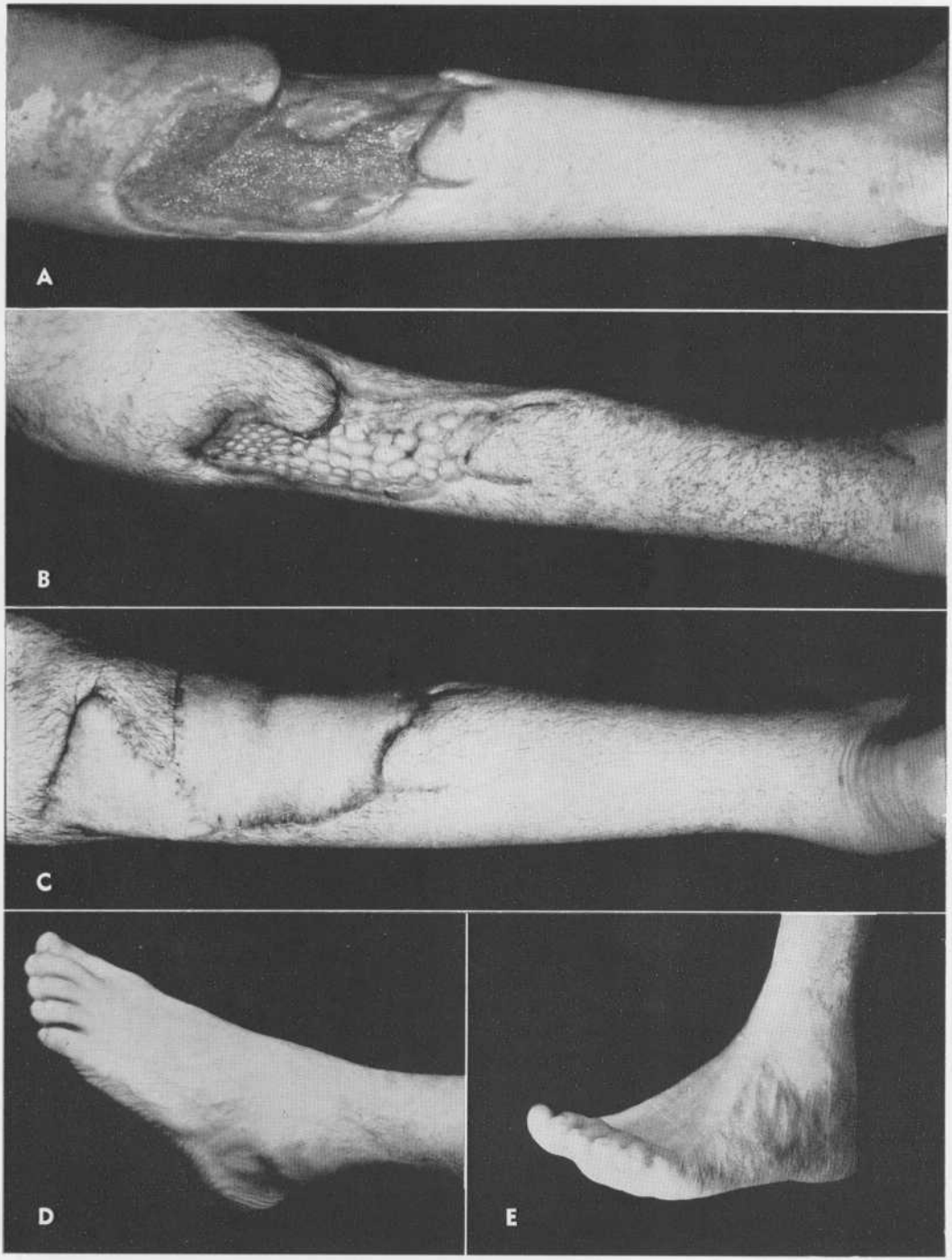
ilium, though the risk of infection always needs careful assessment. If sepsis has been only recently controlled a safer method is the use of cancellous chips to repair bone defects, of course combined with chemotherapy. The resultant restoration will not have the same rigidity as that provided by compact grafting, and the relative risks and advantages must be carefully weighed. Resistance to infection may be locally enhanced by drilling a compact graft so as to increase its content of cellular and vascular tissue, which will actively help in assimilation of the graft and repelling infection. Even in battle wounds with extensive destruction of tissue the success attending reconstruction has been most encouraging with the use of modern chemotherapeutic measures. Plastic operations on tendons may now be more widely practised, but the difficulties are still great, particularly in extensive wounds of the hand. Special atraumatic methods are imperative, and results have been encouraging. One important advance has been the greater success attending early operations on combined lesions of nerve, tendon and skin. Once the original wound has healed chemotherapy may permit the surgeon to effect a useful repair without having to face the later difficulties of contracture, fibrosis and scar formation.

It is convenient here to consider some of the aspects of chronic wounds of soft tissues. In early phases of the war, a large number of wounds, even those of a more trivial nature, took a time to heal out of all proportion to their size. Delayed, arrested or failed wound healing caused an undue amount of hospitalisation and were often responsible, by virtue of the fibrosis accompanying them, for poor functional results, again out of all proportion to the nature or severity of the wound. Such wounds presented a characteristic indolent appearance, their abrupt edges devoid of epithelial activity, and their surface granulations becoming more and more atrophic as they were replaced by more and more fibrosis. Their surface infections usually included infection by haemolytic streptococci. The prevalence of wounds in this state was, at that time, due to three factors:—

(a) There was a rigid and widespread application of the closed plaster technique of wound treatment. This treatment was often continued far beyond the useful period of its early indication and advantages. Even large wounds were often allowed to continue to heal by failing secondary intention with all its stigma of scar formation and contracture.

(b) The secondary infection of war wounds by the haemolytic streptococcus and the adverse significance of this was not duly appreciated. In the mass handling and management of such infected wounds, wound cross-infection and re-infection were rife. Methods of preventing and treating such infections were not so freely or widely applied.

(c) The place of active methods of wound healing as the natural corollary to the modern primary treatment of wounds by excision, was not generally appreciated.



(B. K. Rank)

Results of treatment of extensive tissue loss.

(a) External loss of skin and calf muscles after excision for gas gangrene infection of a gunshot wound.
(b) Early healing effected by palliative pinch grafts applied 3 weeks later.
(c) Final healing after replacement of the scarred area by a soft tissue flap migrated from abdomen.
(d) and (e) Indicate a functional result. There is no scar embarrassment super-added to the initial muscle loss.



To illustrate the method of radical cure applied to many chronic wounds of bone.

(A) and (D) A typical chronic wound of bone.
(B) After opening and preparation of the cavity.
(C) and (E) The final healed result of the soft tissue flap and cancellous bone chip grafts.

The plastic surgery unit at the 2/2nd Australian General Hospital emphatically demonstrated the place of secondary wound closure by skin grafting or other methods for all wounds with skin loss; the earlier this was effected, the better the ensuing result. By a rigid application of aseptic methods of handling wounds, and the use of modern antiseptics and bacteriological control of treatment, surface wound infection could be eradicated or controlled to permit of successful early healing by active secondary procedures. In this regard the use of the sulphonamide drugs was fully applied. Full details of the regime used in this plastic unit in the Middle East will be found in the literature.

In the treatment of established "chronic wounds", after appropriate control of sepsis, re-excision was performed, including removal of underlying fibrotic tissue. The wounds were then closed by suture or graft, with or without a local plastic flap as indicated. The disappearance of the "chronic wounds" as a problem occurred long before penicillin was introduced, but with the use of penicillin and primary or early secondary wound closure, lesions common in 1941 would be regarded as a stigma to the war surgery of 1945.

SKIN GRAFTING

Skin grafting has rightly come to occupy a more dominant position in traumatic surgery. A wound covered with skin is enabled to follow the natural processes of consolidating its repair; the procedures necessary to effect this are not considered as final, and more elaborate techniques may be confidently undertaken later to restore function. This is particularly true of burns and some war wounds. Sepsis is no longer so serious a menace, and preliminary Thiersch or pinch grafting may now be undertaken much earlier with good prospect of success. Exposure to sunlight was found useful in controlling infection on surfaces about to be grafted. In planning a skin graft the choice of method was subordinated as far as possible to the needs of the wounded part. Basil W. B. Riley (Consulting Plastic Surgeon to the R.A.A.F.) described the ideal graft as being thin enough to transplant, and thick enough to give adequate protection with minimum contraction, being of such colour and texture as to match its new environment, and leaving the donor site in such a condition that it will spontaneously regenerate. Not all grafts can do this. In a discussion in London in 1944 it was pointed out that pinch grafts though useful had the drawback of leaving scarred areas on the donor site. They also have a limited cosmetic value, but have been found most useful for early application in injuries like extensive burns in weakened patients with little available donor skin. The Thiersch graft is better from the cosmetic aspect, but the technical difficulties of cutting an even graft are considerable, and useful expanses of skin are sometimes inaccessible to the razor. As Riley points out these drawbacks have been overcome by the dermatome. Its perfection in 1938 has permitted grafts to be cut possessing some of the good qualities of both thick and thin grafts. It is very useful in cutting deep epithelial grafts or split skin grafts. By a special adhesive rubber solution the selected area of the skin is stuck to the drum of the dermatome, and a knife moved

with a sawing motion cuts a continuous graft at a predetermined depth. A very careful technique must be followed to secure exact apposition and suture of the graft to the previously prepared site. Both in civilian and service practice this method has given excellent results. In injuries received in aircraft accidents and from burns the cutting of grafts appropriate in thickness to varied sites such as the trunk, limbs, fingers and face has improved both cosmetic and functional results. An important adjunct to skin grafting is the use of moulds, usually made of acrylic synthetics, by which desired coaptation and pressure can be maintained without irritation.

Whole skin grafts have been found of particular value for their freedom from secondary contracture, a most essential characteristic for use on the face. Of course they require careful dissection. The use of fibrin has allowed more accurate fixation and coaptation of whole skin grafts. It is also valuable in treating the donor site, which often gives rise to discomfort that cannot be disregarded. Bitter complaints are often made by patients of pain in the denuded areas, even though the subject may be sustained by the offered reward of a functional and cosmetic repair his ordeal is none the less. The donor sites left after taking split skin grafts may be treated with fibrin and an analgesic ointment such as 2 per cent decicaine or benzocaine, to the considerable relief of discomfort. Whole grafts also present problems on the donor site; it is not always possible to cover the bare area completely, or to avoid tension on sutures.

Even more elaborate than the whole skin free graft is the attached flap and the tube pedicle graft, which can be long and trying procedures for all concerned. Where large tissue defects have seriously impaired the function of parts migratory flaps have given excellent results. These and other of the more complicated manoeuvres of plastic surgery are best exemplified by illustrations.

In skin grafting we have an old method, now widened in application by improved techniques, more reliable control of sepsis, and the more liberal insight of modern surgery.

SCAR DISABILITIES

Wounds healed with unsatisfactory scars have not been accepted as end results if by treatment that scar can be relieved, improved or transferred to a less vulnerable situation. Apart from the disfigurement itself, scars can be unsatisfactory by reason of instability, their situation on vulnerable areas, or their adherence to muscle with embarrassment of function: they may involve nerves and be painful or tender; they may even become malignant. To these considerations the size and situation of the scar bear a special relationship.

The work of the plastic surgery units has contributed to the diminution of scar disabilities in three ways—

1. By teaching and emphasis that scar is a monument to secondary intention healing to be avoided whenever possible, and that it can be avoided by earliest possible application of the available methods of wound closure, whether as primary or secondary procedures. In latter years, scar disabilities arising from treatment in the early phases of this war have

largely disappeared, and such scar disabilities as arise now require, in general, less radical or tedious and time-consuming procedures. The value of free skin grafts on large surface wounds is clearly demonstrated where grafts are applied on wounds which have already partly healed by secondary intention, or where grafts have been inadequate or incomplete, so that there arise areas for secondary intention healing. The unstable nature of scar, a makeshift integument, as opposed to skin, is always obvious in the behaviour of these wounds. They often break down, not in the grafted areas, but in these areas of secondary intention healing. The sooner a graft is applied to the large surface defect the more satisfactory the result, and the nearer the result approaches the excellence attained by well applied primary grafts.

2. Relief of scar disabilities—In the treatment of unsatisfactory scars in their various manifestation, reliance has not been placed on any fixed or routine method; but all principles have been applied according to the indications of the case. Many are amenable to simple excision and free graft replacement; but a local flap is required where deep scar or structures are involved, and in vulnerable situations. This may be obtained from a local area with or without a free graft on the secondary defect. A direct flap may be indicated, or a migrated flap from other regions. In these cases, tube pedicle flaps have been most extensively used, and applied to all body regions. By these means, a large amount of elective plastic repair has been carried out accepting only the highest standard of end result. Repercussions of this in future invalidity and pensionable disability must be realised.

3. Adequate relief of scar defects have had an important bearing on the application of elective surgical operations for defects of tendon, bone, joints and nerves. By flap replacement of surface defects, many previous difficulties of contraindications to the reparative surgery of these divers structures have been removed.

Large numbers of men with scar disabilities following lesions prior to enlistment were referred to plastic units because of their aggravation or unsatisfactory behaviour under war conditions. Many of these proved very uneconomic to the service, in view of which the paragraphs inserted in recruiting instructions in this regard should be noted. Men with extensive scarred areas, especially on the vulnerable areas of the legs, axilla, hands and neck should not be enlisted for service.

APPENDIX

Technical Instruction No. 24, Middle East.

Treatment of face and jaw wounds in advanced operating units.

These notes are intended to act as a guide to the early treatment of facial wounds on lines most helpful to subsequent management in a special unit. This must generally be done by an advanced operating unit, anaesthetist, surgeon, and dental surgeon (if available) cooperating.

Immobilisation, wound *débridement* and adequate provision of drainage are the aims of primary treatment. Unnecessary delay increases misery and deterioration of general condition—it aggravates sepsis. The following points are advised:—

Soft Tissue Injury.—(1) Wound *débridement* should be thorough but conservative, i.e. only foreign substances and devitalised tissue should be removed. Any small tissue flap may prove valuable to subsequent repair (be extremely careful of antiseptic about the eyes, saline is a good routine lavage agent).

(2) These wounds are all potentially septic. Misguided attempts at primary repair under tension usually fail. This only causes more tissue loss, and displacements which must later be corrected with loss of time. Any established defect with tissue loss should be left.

Retraction is prevented by anchoring loose and displaced tissue flaps with a few catgut sutures in their normal positions. To the same end, suturing skin to mucous membrane about the periphery of defects about the mouth and nasal cavities is a good practice.

(3) Provision for drainage must be made under any pocket or skin flap. Haematoma accumulation must be similarly prevented.

(4) Wounds should not be tightly packed but lightly covered with a few layers of vaseline gauze (plenty of vaseline).

(5) Dirt ingrained in wounds and abrasions as from blast injuries can be adequately removed at this stage by simple measures—using gauze swabs and a stiff brush. If left it can only be removed later by radical treatment or must remain as unnecessary permanent disfigurement.

Bone Injuries.—(6) Conservation of bone fragments. Bone fragments should not be removed from the site of fracture. Their preservation frequently obviates problems of non-union, shortening and bone grafting. Declared sequestra can easily be removed later.

(7) Conservation of teeth. Apart from removing broken particles of teeth as foreign bodies, the dental surgeon should be very conservative. Teeth, whose later removal is indicated, may be of extreme temporary value for jaw fixation or preventing displacement of fragments.

(8) Immobilisation of bone fragments as absolute and in as good position as possible is the prime consideration of early treatment.

Mandible.—Except for a few simple fractures without displacement any form of external bandage does not provide adequate temporary immobilisation for comfort. Any bandage used must have an upward and forward pull, e.g. the "Barrel" bandage. The four tailed bandage is to be condemned. If sufficient teeth are present interdental wiring between three pairs of teeth, using the "eyelet" method is the routine advised, this gives immobilisation in good position against the opposing teeth. With unsuitable disposition of teeth, "arch bars" wired one each to upper and lower teeth and fixed one to the other by wire or rubber bands may be more suited to some cases.

Edentulous patients may present difficulties. Use should be made of any unbroken dentures—otherwise a carefully made mould of dental "compo", or gutta percha (or a vulcanite Gunning type splint), if facilities and time are available. All must be supplemented by external bandage of barrel type, with suitable head gear—rubber dam bandage attached to a head cap is satisfactory. No elaborate forms of treatment should be carried out, which in any way hinders early evacuation to the special unit.

Maxilla.—The same principle applies. Gross sagging displacement of the maxillae is controlled by an inverted tray splint with external arms fixed to a head cap by traction as indicated.

Fractures of Nasal and Upper Facial Bones (often impacted).—Disimpaction with early manipulation into correct positions is indicated. If left this becomes more and more difficult. Retention apparatus is not usually required.

Exit of nasal discharge, blood or C.S.F. should not be impeded by plugging. No form of intranasal splinting should be used, other than a rubber tube with a free lumen.

Post-Anaesthetic Care must be constantly maintained.

A tongue stitch should be inserted before the teeth are fixed. Posture with face down and head low.

If inadequate exit exists for any vomitus, the wires can be inserted but final fixation delayed until patient is well round.

Nursing Care.—(1) Feeding. Early immobilisation is the best aid to feeding. A cup and tube used with encouragement is nearly always quite satisfactory. Nasal feeding is rarely indicated. Prior to immobilisation these people have had little if anything to drink, etc. As much fluid and liquid food as often as possible is indicated.

(2) Mouth washes and toilet as often as possible. Use Sod. bicarb., antiseptic and astringent mouth washes. Supply requisites to self-help.

(3) Salivation is usually profuse, dressings may need frequent changing. A waterproof "bib bag" increases comfort and saves work. It is of great value during evacuation of these cases.

Evacuation.—No advance treatment should unnecessarily delay evacuation to a special hospital.

Cases should be specifically directed to the maxillo-facial and plastic unit where ancillary aids to treatment are available. Send with patients any dentures (whole or partial) and any previous X-rays.

First Aid Treatment—Face and Jaw Wounds.

Correct first aid treatment of war injuries of the face and jaw is often life saving. Death from suffocation or haemorrhage may often be prevented if stretcher bearers and first aid personnel are correctly instructed.

How to Ensure and Maintain an Airway

1. Clear the mouth and throat of blood clot, broken dentures, etc.
2. Posture on stretcher with head over the end, and face down.
3. Control the tongue by posture and tongue stitch with suitable attachment.
4. No bandage should be applied which causes backward traction and increases the difficulties of respiration. Personnel should be familiar with the "Barrel" type bandage. (See below.)

How to Control Haemorrhage

1. When sub-asphyxiation is corrected by control of the tongue and airway, gross degrees of bleeding often cease spontaneously.
2. Plugging of wound cavities, and local pressure on accessible bleeding points, may be indicated.

Patients with severe wounds of this type should never be left unattended.

All nursing and transport should be with the patient lying face down or, if condition permits, in the sitting posture leaning forward.

The "Barrel" Bandage—Any bandage used in the first aid treatment of these injuries should have maximum pull in an upward and forward direction and on no account any pull backwards. The four tail bandage, as illustrated in most first aid books, in many cases is dangerous and contrary to the principles of first aid of these injuries. From experience in the last war, and in this, it has been condemned by all surgeons familiar with this type of injury. The "Barrel" bandage is advised.

About six feet of 2″ or 3″ bandage are required. The middle of the bandage is placed under the jaw, well back, and a simple reef knot tied across the vertex of the skull. This knot is then opened so that the front loop passes around the forehead, and the back loop below the occiput. To exert upward tension, two running hitches are formed just in front and above the ear: the free ends are tied in a reef knot above the head.

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CHAPTER 49

CRUSH AND BLAST INJURIES

CRUSH INJURIES

ALTHOUGH injuries due to crushing or compression of tissues were of great importance in urban areas exposed to air attack, they were seldom seen by Australian medical officers. Nevertheless great interest was taken in Australia in the experimental and clinical work done in Britain on the subject of what was known as the "crush syndrome". The ischaemic necrosis of tissue caused by compression resulted in the liberation of pigment from injured and anoxic muscle, which, even after initial symptoms of shock had been successfully relieved, and after a latent period, caused renal affection and in its severest forms, renal failure. This particular form of the "pigment nephroses" was of particular interest because of the light shed by its study on the vascular physiology and pathology of the kidney. An analogous form was seen in blackwater fever, and, as pointed out in the section dealing with malaria, in this and in anuria due to incompatible transfusion and sulphonamides, similar problems of treatment were encountered. It seems likely that some of the controversy centred round the free administration of alkalies in the treatment of blackwater fever may be clarified by considering the time at which alkaline fluids were administered. Experience with the renal failure of the crush syndrome that fluid and electrolytes must be given early in order to be effective, and might do actual harm if given when the full tale of damage had been inflicted on the renal cortex. Similarly, the effectiveness, or apparent effectiveness, of alkalies in blackwater fever and other forms of pigment nephrosis may depend on the time at which they are given. In service circles consciousness of the urgency of action was well understood, and action was always promptly taken.

A few isolated instances of ischaemic necrosis due to compression injuries followed by renal affection and failure were observed in Australian forces, but do not warrant further special description here. It may be noted that biochemical methods for determining the need for fluid replacement may be usefully applied in these states. These are described in other sections. It is possible that some unexplained deaths occurring several days after abdominal wounds and operation were of this type of anuria due to renal ischaemia.

A full account of the "crush syndrome" will be found in the British Official Medical History of the 1939-1945 war.

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BLAST INJURIES

Australian experiences in blast injuries were limited. Civilians were involved in a few episodes only, but members of the Services exposed to air attacks or bombardment furnished a number of instances. Knowledge of the mechanism involved has been gained only since the wider adoption or more wholesale methods of killing, and hence dates back to the Spanish Civil War. An account of blast injuries was compiled for publication under the direction of a committee of the Medical Research Council of Great Britain. This sets out the physical phenomena responsible for bodily injury. The factors concerned in production of "blast" are the creation of an air wave of increased pressure, followed by a recoil wave of decreased pressure which produces a more or less violent movement of air in the wind caused by dispersion of the gases of explosion. The positive wave may build up great pressure, but this subsides rapidly, thus accounting for the capricious sparing of human bodies in the neighbourhood. The negative wave lasts considerably longer than the high pressure wave, and is thought by many to be more active in inflicting physical damage. Inanimate objects may also be shattered by the wind of the explosion.

"Pure" blast effects were seldom seen. Australian experience has been that men might be killed by blast without much external evidence of injury, but if they suffered non-fatal injuries, they often had some other form of trauma as well, such as head injury, fracture of bones or burns. Abdominal injuries were occasionally seen, but the pulmonary effects were much more common. In some abdominal injuries due to the effects of explosive weapons, such as bombs or grenades, damage caused by blast was also observed. This added to the gravity of the obvious intra-abdominal injuries. Typical instances were described by Majors T. F. Rose and D. Watson. In lesser degrees of abdominal blast subserous haemorrhages of the viscera were probably responsible for the symptoms of distension and tenderness: spontaneous recovery could occur. In more severe injuries extensive extravasation of blood was found in the hollow viscera, though recovery was still possible if any disruptive lesions were repaired. Pulmonary blast injuries sometimes accompanied the abdominal damage and added greatly to the seriousness of the outlook. The most striking signs of pulmonary blast were shock and dyspnoea. A close resemblance was sometimes seen to the symptoms caused by injury received in road accidents in which a man might have his thorax violently though momentarily compressed by being hurled against some solid object. In the 2/11th A.G.H. and the 2/13th Field Ambulance in Alexandria numbers of blast injuries were seen in men on the *Orion* on 29th May 1941, when this ship underwent violent air attacks during the evacuation of troops from Greece. A number of men died rapidly, others suffered severe dyspnoea and cyanosis. Other similar injuries were seen following air raids in Alexandria. Of one series of 20 men seen in the 2/11th A.G.H. half had uncomplicated blast, and one fifth died. Oxygen and morphine were invaluable, though difficulty

was found in administering oxygen to men with burns of the face. Sulphonamides were given to counter bacterial infection, a complication observed in about half the men. The pulmonary indications for treatment in this series outweighed those resulting from shock, though signs of shock were also present, and resuscitation by intravenous fluids was not attempted.

Some instances of severe blast were also seen following the air raids on Darwin. Medical officers on naval ships also treated men with blast injuries due to bombing or gunfire, though here too multiple trauma was common. A special type of blast was that occurring during immersion in the water. In this both thoracic and abdominal injuries were encountered: of course it is impossible to say how many of these were fatal, but observation of survivors shows that the effects of immersion blast were usually severe. In this type it is evident that a compression wave must be the important factor in producing the injury. Life jackets afforded some protection.

The anatomical lesions found at autopsy were mainly haemorrhagic in nature. Owing to the tearing of alveolar walls and their contained capillaries, they were mostly seen along the ribs. Blood was usually found in the upper air passages, though no local damage was evident. No signs of external injury might be found.

In fatal injuries on land it was often difficult to determine whether death was due to the effects of a high compression wave alone or of violent contact with the ground or other objects. Cerebral damage without injury to the skull, that is, closed head injury, might also be due to either cause.

Although the outmoded term "shell-shock" was forbidden in describing psychiatric states associated with air attacks, men with psychoneuroses often attributed their condition to damage from air attacks. Sinclair, in describing psychiatric affections in New Guinea, pointed out that it was desirable to have criteria by which a man's medical history could be assessed in this regard. He found that a history of being dazed after the alleged exposure to bombing was not acceptable evidence of any causal relation. The only immediate sequels which could be relied on were:

(1) loss of consciousness after the explosion with recovery after a few moments due to mild concussion, or after a longer time, when cerebral irritation or lesion might be caused;
(2) bleeding from the nose or ears, or injury to the ear drums; and
(3) coughing of blood.

No special observations were carried out on the anatomical basis of blast, but such autopsy evidence as was obtained was in conformity with the well-known pictures.

Treatment chiefly followed the usual régime of rest, warmth, morphine and oxygen, refraining from intravenous fluid therapy as a rule, owing to the risks of pulmonary congestion. It was found that patients with these conditions, like all those suffering from pulmonary disturbances or from potential abdominal injuries, could not tolerate movement with safety, and should not be subjected to travelling.

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CHAPTER 50

ACCIDENTS

CONSIDERABLE wastage of men occurred in the Services through accidents. Even in the first year of training in Palestine many accidents were caused by sport, by falls into slit trenches or over the various obstacles peculiar to camps, especially at night during black-outs. The comparative frequency of fractures of the scaphoid bone in the wrist may be mentioned, as it was the cause of a good deal of lost time. Failure to unite even after prolonged immobilisation sometimes necessitated operation for excision.

There is a tendency in all communities to accept traffic accidents with a certain degree of complacency. If this existed in the A.I.F. in the Middle East it should have been shattered by a report by Lieut-Colonel F. J. Clark, in charge of the surgical division of the 2/7th Australian General Hospital in Palestine on his personal experiences in this hospital.

He pointed out that comparison with the figures of accidents treated in civil hospitals was not valid as the very young and the old were not concerned in army figures, which refer only to strong young men. Most of the patients in this category were injured in road accidents, though a number also were suffering from burns. The first patients admitted to this hospital were six officers involved in a motor car smash; four of them died. From May 1941 till March 1942 the hospital was working practically to its capacity of 1,200 beds. The monthly average of accidental injuries necessitating admission to hospital was constantly about 100 during that period, the total being 1,033 in ten months. During the same period the total surgical "new" admissions were 4,656. Nearly one-third of the officers admitted had suffered accidents; for other ranks the proportion was roughly one-fifth. Of the surgical admissions 579 were for battle injuries over a period of two months during the Syrian campaign. It is significant that during a period in which 568 patients were received with combat injuries, 287 were admitted as the result of accidents.

Review of admissions for infectious disease for the whole period showed that accidents accounted for more than half the number treated for infections, and during the months of their greatest prevalence malaria and relapsing fever caused very few more casualties than accidents. In fact, accidents were responsible for nearly one-twelfth of the total in-patient work of the hospital for ten months. Half the deaths in the hospital were due to accidents.

Investigation of this series showed that although the narrow roads of Palestine and inefficient lighting of vehicles were hazards, speed was the most important factor. Alcohol was also important: many of the men admitted thus were in varying degree under the influence of alcohol. This was particularly so at night and applied specially to officers. To what extent defective vision or adaptation in the dark was significant could not

be stated. It must have been relevant in some instances, for test by an ophthalmologist of a random series of soldier patients showed that quite a number had such poor dark vision as to make them inefficient for driving in a black-out. Some of these were army drivers.

Similar observations were made in other hospitals. In November 1941 the officers' surgical ward at the 2/1st A.G.H. at Gaza Ridge was practically full of officers suffering results of motor accidents. A suggestion was even made to constitute a special court to deal with these cases. In 1943 in Australia the same trouble was found. The 2/1st A.G.H. then at Guildford again found the number of serious motor accidents very disturbing.

In the later stages of the war, while the 2/7th Hospital was in New Guinea, at Lae, Lieut-Colonel Newman Morris made some observations on the accident rate due to sport. Reference has been made elsewhere to the number of injuries to wrists, knees, etc., in Palestine from the same cause. Owing to interruption in the New Guinea enquiry only a small series could be assembled, but over a period of 100 days 80 patients were admitted as the result of accident. Of these, 36 had injuries sustained during sporting activities. Without comment it may be mentioned that 18 were inflicted by Australian Rules Football and 13 by Rugby, the total time lost thus being at least 122 weeks for Australian Rules and 31 weeks for Rugby.

It was not thought that this incidence was excessive, because regular football competitions were held in Lae. Nearly half the remainder of the accidents were due to mishaps to skilled labourers while doing their usual work. Only three were due to road accidents. The balance, 22 out of the total 88, were due to accidents of other types, only three being due to burns.

No statistical conclusions can be stated from these sets of observations, but in New Guinea lessened opportunity for road adventures, and possibly better control of speed, and, it is hoped, a greater degree of wisdom applied to the prevention of mishaps, all combined to lessen the rate in some directions. The greater difficulty of obtaining alcohol was also an advantage.

In general, it may be said that accidents of the civil type can be an important cause of wastage of men, and preventive measures should be taken where possible.

CHAPTER 51

NON-URGENT SURGERY

BY "non-urgent" surgery is here meant surgery directed towards the relief of disabilities usually mild in degree, interfering with the health or efficiency of servicemen and women. These conditions were unrelated to war wounds, and usually also to war service, and were of such nature as to be best carried out in well equipped surgical units in settled areas. An instruction (Technical Instruction No. 8) directed that no such work could be carried out in field ambulances except by special assent of the local administrative medical officer. Naturally any condition requiring immediate surgical relief could be carried out in any appropriate unit.

Surgical ailments occurred in the Services just as in civil life; some were related to accidents or stress of training, others to the emergence of physical disabilities in the ordinary course of military life and chiefly related to age. There were also numbers of minor troubles which were considered important only by the man himself. For example, deflection of the nasal septum, which may have caused no substantial trouble in civilian life, may be discovered only during routine examination for, say, some mild infection. It would not be necessary, or even advisable to perform radical cure. Some elasticity of judgment must of course be allowed to responsible surgical officers. For example, pterygium undoubtedly increased in rate of growth in the Middle East and caused increasing local irritation. Whether surgical treatment was advisable or not would in this instance depend on the military position as much as on the man's symptoms. The importance of common orthopaedic conditions was often made manifest or more conspicuous on training. The action taken rested on surgical experience and judgment. A special technical instruction (No. 25) was issued on disabilities of the feet. This directed that surgical operations for their relief would not be undertaken in hospitals of less than 600 beds. Operations involving amputations of toes in these non-urgent states were forbidden, also operations on severe disabilities such as *hallux valgus* and *pes cavus*. In fact the only indications for operation were the presence of disabling pain and the hope of stabilising or improving the soldier's standard of fitness. The detailed directions were given in Technical Instruction No. 25, appendix, Chapter 40.

Operations on large joints were regarded seriously, and Technical Instruction No. 20 laid down that operations for internal derangements of the knee joint would be performed only in general, base or orthopaedic hospitals. This is further referred to in the orthopaedic section. Other types of "interval surgery" were also controlled by a definite policy. Camp hospitals and field ambulances were not allowed to carry out work of this type, and only performed such urgent operations as were made necessary on the spot by geographical or tactical conditions. Field ambulances acted as operation units only in emergency or when specially

detailed to do so. This policy ensured that deliberate surgery should be performed under the most ideal conditions.

Inguinal hernia was a common non-urgent operation. No large series of collected figures are available concerning the services throughout Australia. Harley Turnbull, in a reply to British critics of the Bassini-type operation has assembled a total of 700 operations for hernia performed in a large base military hospital. Of these hernias, 52 were recurrent, which gives the rate of recurrence in the Australian Army as 7.5 per cent. Turnbull suggests that the rate among civilians subjected to less average strains should be less than this figure. It will be observed that this rate is considerably lower than that shown in some series in the literature. The operation most frequently performed was the Bassini or a modification. N. R. Wyndham, writing on the subject of recurrences, records some details of 106 patients seen in a repatriation hospital. It is not known what percentage of recurrence this figure indicates, but it shows that the problem is still a considerable one. The hernia had recurred within two years of operation in 70 per cent and within one year in 40 per cent. Accurate details are not known of the techniques employed; as already mentioned, the operations were usually based on the Bassini method, and silk seems to have been the most frequently employed suture material. In Nakom Paton in Thailand over one hundred herniotomies were performed by order of the Japanese. Though the facilities were limited little trouble was experienced in the post-operative period and the results were satisfactory. Where the posterior wall of the inguinal canal was defective a modified Willys Andrews type of repair was done, with the use of cotton sutures. An interesting light on the temporary loss of men to a fighting force is given by Turnbull. Seven hundred operations performed in one hospital over a period of eighteen months immobilise a full battalion of men for three months.

Operations for appendicitis need no special mention except to remark that a careful collection of records of servicemen suffering from acute attacks of appendicitis might be illuminating if the co-existence of other infections was noted.

In the section on dysentery the diagnostic difficulty has been mentioned; T. F. Rose's article there quoted rightly points out that carefully taken histories, and careful physical and pathological examinations are advisable if errors are to be avoided. Undoubtedly involvement of the appendix in a bacillary or amoebic dysenteric condition occurs and may demand appendicectomy, but operation should not be performed unless firm indications exist. Malaria has also confused the issue on occasion, particularly with infections by the malignant tertian parasite. Intravenous quinine has solved the diagnostic problem more than once. The same, of course, applies to a number of acute conditions which may be simulated thus.

Acute appendicitis as seen in civilian communities would be also worthy of close study in a military community, especially where runs of the disease occur almost of epidemic type. For instance the 2/12th Australian General Hospital reported that during the combined operations on Balik-

papan appendicectomy was performed 28 times, and practically all the men had acute appendicitis of severe kind. Gangrenous changes were noted early in a high proportion, and one death occurred after operation. No cause was proven, but it was surely infective.

A common non-urgent operation was that for pilonidal cysts. A congenital factor has been suggested for these, but E. S. J. King has thrown doubt on this. It is possible that trauma from physical strains of various kinds in training or during military service may have been a determining cause. King has stressed the progressive nature of the lesion, which he thought began by a process of pitting into the subcutaneous tissue. The chief difficulty in dealing with these "cysts" was that of entire removal; obliteration by careful dissection and suture was the most practical method under service conditions. Venous varices in their different locations were a source of much trouble in the services. Varicocele was not considered an indication for operation at all, a contrast from the earlier periods of the 1914-1918 war when men with trivial and symptomless varicoceles were required to undergo operation before they were accepted as recruits.

Varicose veins in the legs caused a good deal of lost time in the Services. The popularity of simple injection with a sclerosing agent has been dimmed in recent years by a high percentage of recurrences. It was as Ogilvie calls it "a craze of the twenties". This wave having passed, the more comprehensive procedure of saphenous ligation and retrograde injection has gained ground. C. H. W. Lawes has pointed out that the military clinics for varicose veins had some of the evils of many civilian clinics with their multiple attendances of patients for repeated injections. Medical officers on recruiting boards saw many men with varicose veins. Most of these varicocities were not extreme, for the advanced lesions automatically rendered a man unfit, and the majority of these men could be cured with appropriate treatment. For this hospital beds were needed, but hard to get. The weak point lay here, as Lawes showed; men would have injections with temporary relief, and after enlistment would later help to swell the varicose veins clinics, particularly in the Middle East. Had the services accepted the responsibiltiy for treatment in recruits, or at least its direction by very careful selection afterwards the position would have been better. It must be admitted that many men of sedentary habit with slight varicose veins acquired a real disability after taking up military duties entailing much standing and marching and not a little hard work.

Haemorrhoids and other rectal and anal disabilities were considered of sufficient importance to form the subject of a special technical instruction (No. 24). These conditions were relatively common in the Services. The instruction embodied diagnostic information, and suggested the course of action necessary in each case. Minor degrees of these ailments were not considered disabling enough to warrant interference.

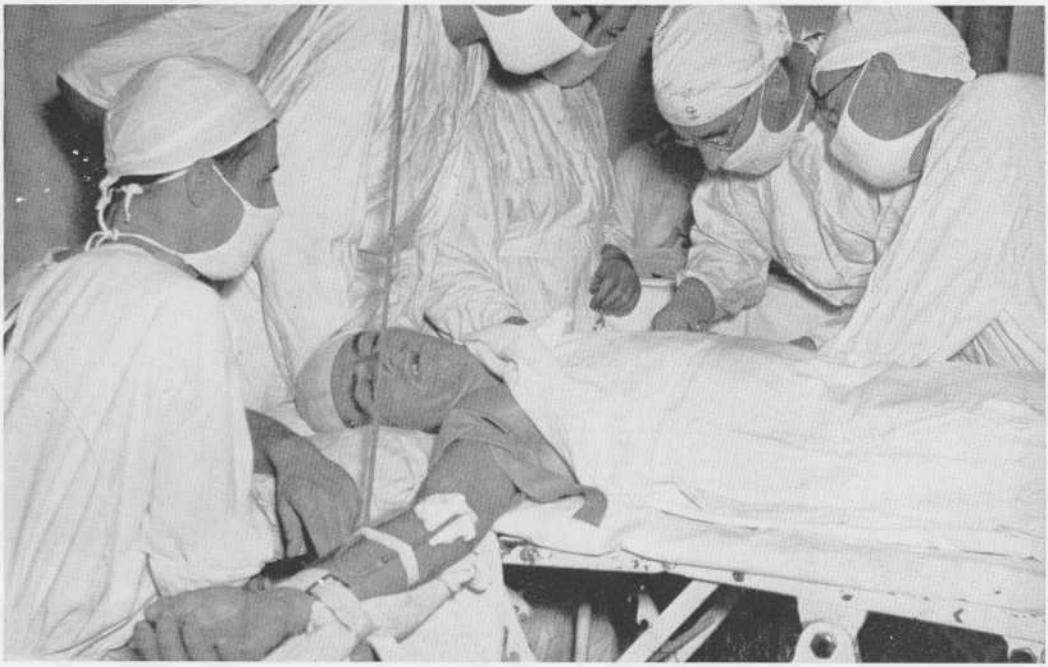
Treatment recommended was as follows: for recent external haemorrhoids under tension, incision and evacuation of the clot; for old lesions of this kind, no action; for self reducing internal haemorrhoids with slight bleeding only, the usual general and local measures. Only prolapsing or

actively bleeding lesions needed surgical treatment, which was not carried out in the unit but in a hospital. Small anal or acute ischio-rectal abscesses might need incision by the unit medical officer, but ischio-rectal abscess and fissure were indications for transfer to hospital for adequate treatment.

Surgical conditions requiring admission to hospital, even when non-urgent in type, called for not a little judgment by the unit medical officer, as he had the opportunity of assessing the soldier's disability in its true relation to health and to military service.

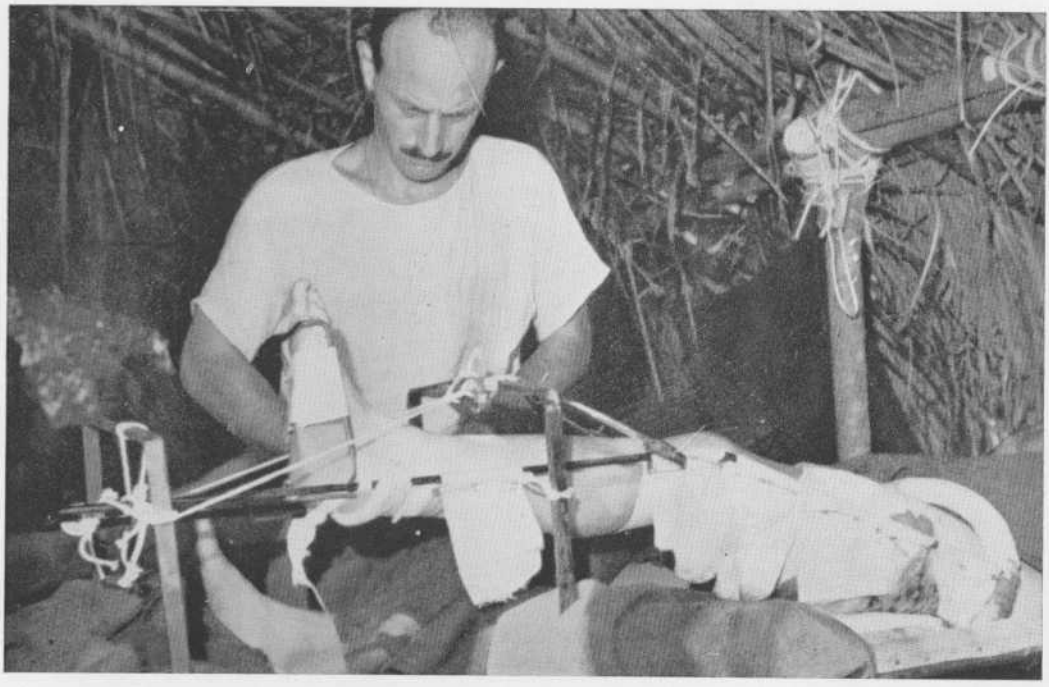
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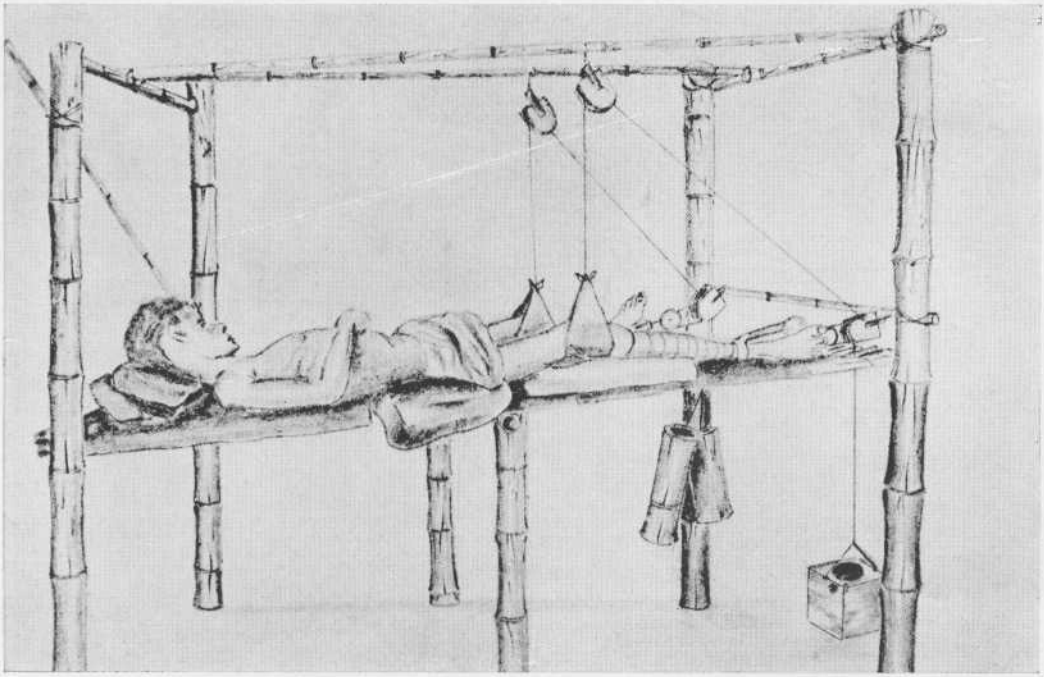
(Australian War Memorial)

Operation on nerve of upper arm at Tarakan.



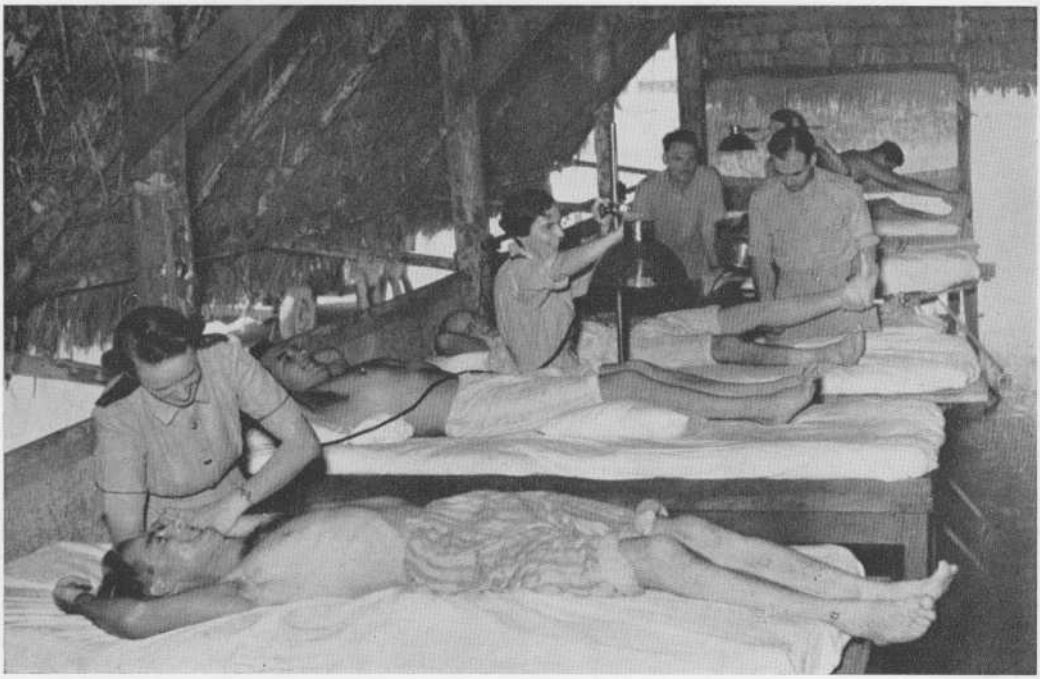
(Australian War Memorial)

Major J. Loewenthal using improvised method of fixation of compound fracture at New Guinea forward medical post.



(Drawn by P. Meninsky)

Illustrating leg weights, jungle pattern of Hamilton Russell extension: Chungkai.



(Australian War Memorial)

Physiotherapy Department, New Guinea.

CHAPTER 52

ANAESTHESIA

UNDER service conditions the giving of anaesthetics varied perhaps more widely in medium and method than any branch of work connected with surgery. The methods chosen depended not only on technical indications but also on the local conditions, the anaesthetic agents to hand, and in particular, the anaesthetists available. Thus dental officers frequently gave admirable service as anaesthetists in time of stress and difficulty, and so lightened greatly the responsibilities of operators in forward surgical teams. Some orderlies, too, attained considerable skill, and became adept at such procedures as venepuncture. During the Wau campaign a surgeon in a forward area operated on a man with an abdomino-perineal wound under ether administered by an inexperienced orderly, there being no medical officer within a day's march. In rushes of surgical work medical orderlies were invaluable, as during the battle of Tarakan, when bulk solutions of "Pentothal Sodium" were prepared, and given to successive patients by means of a dripper and tubing attached to a container hanging from the theatre lights. The supervision of such assistants was thus greatly facilitated. Even chaplains gave willing help with anaesthetics, especially in the immediate after-care of unconscious subjects, and in the making of records.

During the early training periods in Palestine spinal anaesthesia was used extensively because large stocks of "Percaine"[1] 1 in 1,500 solution were to hand, while only a moderate amount of ether and little else were available. As a temporary measure an antique gas and oxygen machine was occasionally used by the pioneers until machines of the standard "Austox" model were available overseas. Great difficulty was encountered at first in obtaining enough anaesthetic gases, chiefly owing to shortage of containers, and to technical problems of refilling. Eventually decanting apparatus for oxygen and nitrous oxide was made in Australia and sent to the Base Depot Medical Stores in the Middle East. Later the shortage of cylinders was overcome to some extent, and adequate supplies of oxygen were obtained locally. One difficulty arose in the need for adapters to enable British gas cylinders to be used in the Australian gas machines. A prototype adapter was made for this purpose by Major G. Kaye of the 2/2nd A.G.H., who was the adviser in anaesthesia to the A.I.F. in the Middle East. Several other items of equipment were devised in this way, and with the help of the Australian Army Ordnance Corps, duplicated for local use. Major J. F. McCulloch, of the 2/1st A.G.H., having at first no endotracheal machine, had a Flagg's can made from a jam tin, and other units used cans of various "models" till a number were supplied of standard type.

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[1] At this time the name had not been changed to "Nupercaine" in British countries.

After some time equipment and agents became well standardised and increasingly available in most fixed units, while the more mobile medical units were able to meet all reasonable demands for anaesthesia with existing facilities. Nevertheless, several desirable items were either lacking or most inadequately supplied during the first 2 or 3 years of the war, despite strenuous representations from experts. For example, after the formation of the 2/6th A.G.H. in mid-1940, recommendation was made for the supply of "heavy" "Percaine" and "Neosynephrine Hydrochloride" for use in spinal analgesia. In addition, the necessity for cyclopropane gas was stressed, and it was urged that the official supply of "Pentothal Sodium" for the hospital should be greatly increased. These requests were refused, since all items except the last were not included in the existing drug scale. Consequently supplies were bought privately and taken abroad with the unit, later to be lost in Greece. During the next 18 months, certain drug firms in Sydney kindly sent over small quantities of various items from time to time. It was not until the latter part of 1942, however, that some of these essentials became more freely obtainable, largely from the stocks of the British Force in the Middle East. Meanwhile "Pentothal Sodium" was rightly and almost entirely reserved for use in forward areas, issues to fixed units being very limited. This realization of the great value of intravenous anaesthesia in the field was influenced by experiences of its use during the evacuation of Greece and Crete, reported by Major S. V. Marshall.

The earlier and continued use of spinal analgesia on a large scale was an example of adaptation to prevailing circumstances. "Pentothal Sodium" was scarce, for its value had not been properly recognised. Much of the ether, sent over in 5 lb. cans, was of dubious quality, since under the climatic conditions of the Middle East the tins "blew"; air got in during the cool nights, resulting in the deterioration of the contents. This was a contributory cause of the high incidence of pulmonary complications in that area. Nitrous oxide and oxygen anaesthesia, of course, was quite inadequate for the robust type of subjects encountered.

Consequently the use of spinal analgesia perforce was extensive in fixed units. It became almost a routine in operations for hernia, appendicitis, haemorrhoids, etc., and later served well for many of the longer procedures on the lower limbs. It was not very popular, however, with some surgeons and many patients.

Although not generally representative, McCulloch's series of over 5,000 cases of anaesthesia, either given or supervised personally, illustrates the influence of local circumstances on the methods chosen. In his report the anaesthetics used were distributed as follows: 1,884 (38 per cent) were spinals, using at first "light" and later "heavy" "Percaine"; 994 (20 per cent) ether anaesthetics were given; while chloroform was used occasionally for inductions or brief procedures. Nitrous oxide was used in 144 (3.5 per cent) cases, and cyclopropane in 22 (0.5 per cent). Against this the intravenous barbiturates were used solely in 1,396 (28 per cent) cases, and combined with ether or gas in 489 (10 per cent).

Experiences and adaptations in the Pacific theatres of war followed largely on those of the Middle East. In Australia anaesthetic work was less dramatic than that in forward areas overseas, but none the less important. On 27th January 1940 a special article was published by W. I. T. Hotten which traversed the indications for anaesthetic equipment and practice in military units and surveyed the needs for all types of regional surgery. Later, in 1942-1943, when the calls on manpower were heavy the special needs of anaesthetic services in the base hospitals in capital cities became more pressing. The arrangements were at first along the lines of civil hospitals, but it became evident that a responsible officer must be available who could devote his time to the direction of anaesthesia, and that more anaesthetists must be trained. The adoption of these measures at Concord Military Hospital led to improvements there and elsewhere, and a large number of competent anaesthetists were thus trained, greatly to the advantage of civil practice after the war.

A *Manual of Army Anaesthesia Apparatus* was compiled by Major G. Kaye in the Middle East and this was published in Australia in 1942 and circulated to all medical units. It helped greatly in the understanding of the various forms of apparatus and their maintenance.

An important duty undertaken by most hospital anaesthetists was the care of the oxygen apparatus. At first this was scarce and primitive, and many improvisations were contrived. As more of the B.L.B. type of mask became available a standard method became possible and so a greater efficiency and economy in this form of therapy.

We may now pass to the detailed consideration of the various anaesthetic methods practised during the war.

SPINAL ANAESTHESIA

This method was found most useful in surgery of the "interval" or civilian type, especially when anaesthetists other than medical officers already busy in ward work, were few. The 1 in 1,500 solution of "Percaine" was used chiefly during the Middle East period, being later replaced by the 1:200 solution made hyperbaric with 6 per cent glucose. Where a higher level of anaesthesia was required either Lake's procedure or the method of entering the spinal theca with the patient prone were found useful, when by suitable posturing control of the analgesic level was simplified. Thus 10 to 12 c.cms. of the light solution were usually not exceeded, while up to 2 c.cms. of the heavy solution were generally sufficient. Adjuvants were sometimes necessary. Where adequate premedication was possible with the barbiturates or opium derivatives less discomfort was felt, but when this was lacking morphine given intravenously at short notice was occasionally found very useful. Nitrous oxide with oxygen when available was sometimes used with good results, and also "Pentothal Sodium".

Minor complications, such as headache, backache, urinary retention, *et cetera,* were fairly common. Care was taken to avoid subjects who had previously had meningitis, head injuries or any other central nervous

affection. In 1942 in the Middle East a considerable incidence of meningeal irritation was noted after spinal anaesthesia. This followed the use of one particular batch of light "Percaine" solution. The trouble ceased after this supply was withdrawn, but recurred when it was inadvertently reissued to a relieving unit. In consequence surgeons became rather hostile to spinal analgesia, the use of which tended to decline since good locally made ether and more "Pentothal Sodium" now became available. Happily the victims of these alarming events knew little of them, because the severity of their symptoms required the free use of amnesic sedatives. There was no doubt that the cause was irritative, residing in either defective preparations or breaches of technique. Accordingly a special instruction was issued (No. 72) drawing attention to the need for rigid care in the sterilisation of syringes, needles and all containers, and insisting on the use of sterile distilled water for all rinsings. Meningeal irritation followed the use of "Percaine" in both the 1:1,500 and 1:200 strengths, although by far more common with the former preparation. While the contamination of apparatus and materials with antiseptics, *et cetera,* may have been significant, it is very probable that some change in the pH of the agents provided was the chief factor involved.

In Japanese prison camps inhalation anaesthesia was possible only in a more or less settled area like Changi, where limited supplies of ether and chloroform could be obtained. Over 350 anaesthetics were administered in Changi Hospital for the year ending December 1944. Chloroform and a little ether were then available, as well as some "Pentothal Sodium" and "Percaine" and a very small amount of nitrous oxide. In the hospitals in working camps in Burma and Thailand and in the huge hospital area of Nakom Paton little surgery would have been possible had not local and spinal anaesthetics been available. In Nakom Paton spinal anaesthesia was used for operations on the abdomen and lower limbs. In Thailand Lieut-Colonel Coates and other surgeons associated with him found that their stocks of "Stovaine", procaine and "Novocain" dwindled rapidly. Tablets of Japanese cocaine were available and with caution less than the proposed dose of 40 milligrammes was used, 0.5 c.cm. of 2 per cent solution. Further trial showed that 0.75 c.cm. of this solution was safe and effective. Less fall in blood pressure was observed with cocaine than with "Novocain". No headaches occurred after the injections until a syringe was used which had been sterilised in alcohol. It was thought that traces of methyl alcohol may have caused some headaches At Nakom Paton "Cutocaine", 2 millilitres of 4 per cent solution, was used from Red Cross supplies during the last year. Occasionally atelectasis was found after spinal anaesthesia. The only serious sequels encountered in this Burma-Thailand experience were due indirectly to the growing of moulds in solutions of "Percaine". In order to conserve the material attempts were made to prevent the persistence of spores and unfortunately the changes set up in the "Percaine" solutions caused paralysis in two instances, with fatal results.

INHALATION ANAESTHESIA

This was, as usual, the standby where ether of good quality was freely available. Not all the modern advances or the mechanical aids to anaesthesia have supplanted the "rag and bottle" method of "open" ether. Rather have the factors of good training and skill enhanced its utility and safety, so that it became the method of choice for anaesthetists of average competence. Thus "open" ether sufficed for a large proportion of the anaesthetics given under service conditions, in both forward and base areas. Further, the simple principles of the method could be readily adapted to surgery about the head and neck, by using the Flagg can and a Magill endotracheal tube, suitably connected. Thus the surgeon had free access, and the anaesthetist retained adequate control.

Apart from very short procedures ethyl chloride was not much used as the sole anaesthetic agent, but it retained widespread popularity as a preliminary to ether. In the later stages of the war it was largely supplanted in these respects by "Pentothal Sodium". Chloroform, as forecast by some of those who used it extensively during the 1914-1918 war, was again found quite useful. Its use as a preliminary to ether may not be pharmacologically ideal, but for difficult subjects like young robust soldiers it had a place at times, while as an adjuvant it was occasionally of value. Chloroform and ether, mixed in the proportions of "C1:E2" or "C2:E3" proved very useful for induction purposes when ethyl chloride was in short supply. Sometimes no other choice than chloroform was possible, for example, at night with naked lights in the theatre, and the only other available agent ether. In prisoner-of-war camps on Singapore Island chloroform was used chiefly because little ether could be obtained. In no less than 193 out of one series of 259 anaesthetics chloroform alone was the agent employed.

Difficulties in the induction of ether anaesthesia were not infrequent. The climate of Palestine and Egypt or of the Pacific Islands was blamed by some, but similar conditions were familiar to most Australian anaesthetists. The universal and often excessive addiction to tobacco of the Australian soldier may have been a factor, but attempts to limit his smoking before operation were not very successful. It is more likely that the two main relevant factors were the physical nature of the patient and the nervous tension common under service conditions, which are certainly not those of home to the average man. Mechanical aids to ether administration were available to most medical units in one form or another. The somewhat outmoded Shipway apparatus was portable and useful to field units particularly. An insufflation apparatus, powered by either electric motor or foot-bellows, was available for endopharyngeal or endotracheal anaesthesia in units of the fixed or semi-fixed type. As above mentioned, Flagg's cans could be supplied or were simply extemporised; they had the great advantage of portability and independence of mechanical factors, but required the passage of a wide-bore Magill tube for effective use.

Late in 1942 an Oxford vaporiser was issued to the 2/6th A.G.H. from Base Depot Medical Stores, Middle East Force. About the same

time some trichlorethylene ("Trilene") and cyclopropane gas were acquired from the same source. Subsequently many other units, both abroad and in Australia, received Oxford vaporisers, which gave invaluable service. Most suitable for endotracheal (Magill) ether anaesthesia, and even adaptable to trichlorethylene, their great virtue was that little attention was required in their safe and efficient operation, once this was properly established. Thus the concurrent supervision of other anaesthetics during busy periods was much facilitated. The Oxford vaporisers were very useful in tropical climates, particularly for facio-maxillary work.

As indicated above trichlorethylene ("Trilene") became available in the later stages of the war. A volatile agent of comparatively high boiling point (87°C.), it has valuable analgesic properties, but is not suitable for general anaesthesia. It was tried by various users as an adjuvant to nitrous oxide and oxygen, with somewhat inconclusive results. At the 115th (Heidelberg) Military Hospital, however, it proved admirable for various types of plastic and reparative surgery and subsequently was found most helpful in neurosurgery, especially as a supplement to "Pentothal Sodium". A. L. B. Webb has described its application in the services. Rather prolonged drowsiness was sometimes noted after its use, and one instance of temporary diplopia was reported.

Although extensive preparations were made for the use of nitrous oxide and oxygen anaesthesia in both fixed and mobile units, it did not achieve widespread utility during the recent war. Anticipations based on its accepted superiority over chloroform, and even ether, under the conditions of the first world war were not realised. In those days the combined effects of haemorrhage, shock, sepsis, and toxaemia, together with the inadequacies of treatment then current, made anaesthesia a grave and often fatal hazard. In these circumstances the use of nitrous oxide and oxygen instead of more potent agents led to a substantial reduction in the mortality of serious battle casualties.

Working on the foregoing assumptions, Major Kaye submitted a report to the responsible authorities on the "Estimated requirements of medical gases for an expeditionary division of 20,000 troops". He also undertook strenuous activities connected with the design and manufacture of the "Austox" field service apparatus, which was intended to fulfil the heavy demands envisaged. All base hospitals, hospital ships, casualty clearing stations and even field ambulances were issued with these machines, which were sturdy, compact and portable. They incorporated attachments for supplementary ether and carbon dioxide absorption, and could even be adapted to the use of cyclopropane gas if available. Despite the good qualities of this apparatus, its utility in practice was limited, partly because a high degree of skill was required for its successful operation, and partly because other methods, intravenous anaesthesia in particular, were more simple and effective.

Even in base hospitals and certain fixed units, to which trained anaesthetists were posted, nitrous oxide and oxygen anaesthesia was not used extensively, although the combination acted as a satisfactory vehicle

for more potent agents, such as ether, cyclopropane and trichlorethylene. Under the mobile conditions encountered in the field, however, its employment was quite impracticable. The evacuation of casualties, resuscitation therapy and the control of sepsis were so efficient that "open" ether or, later on, "Pentothal Sodium" could be safely given in almost every patient needing immediate surgical treatment.

Nevertheless, most base units employed the method quite freely for subjects weakened by shock, cachexia and toxaemia. In these its combination with basal "Pentothal Sodium" or supplementary ether in small dosages was very satisfactory. For such applications it really was indispensable. Even in the Changi Barracks Hospital on Singapore Island a small quantity of nitrous oxide was available for use in selected cases. In addition, the value of nitrous oxide and oxygen was demonstrated in April 1944 by the staff of the 2/2nd Australian Hospital ship *Wanganella* at Bombay, when they were called upon to render surgical aid to a number of men very severely burnt and wounded in an explosion on a ship in the harbour. Two surgical teams worked almost continuously for nearly 24 hours, and gas anaesthesia, alone or with ether, was used most successfully by Captain W. F. L. Liggins who had had recent training in the use of the "Austox" field service apparatus at an instructional course at Concord Military Hospital.

Owing to its low potency nitrous oxide and oxygen anaesthesia was unsuitable for robust subjects, such as strong young men, and so was not infrequently supplemented with ether in lavish quantities. In such patients air, perhaps enriched with oxygen, would have been a better and more economical vehicle for the real anaesthetic agent. Yet gas and oxygen given by the carbon dioxide absorption technique offered certain advantages, even if ether had to be added. It reduced the loss of heat and fluid by the patient, and lessened the risks of ignition. In addition, great savings of both nitrous oxide and oxygen were thus effected. Major G. Kaye's series at the 2/2nd A.G.H. in the Middle East showed an average consumption of 200 gallons of nitrous oxide in 6¼ hours, figures several times better than those possible with the "continuous flow" procedure.

Other minor troubles hampered the use of nitrous oxide and oxygen anaesthesia, at any rate in the Middle East. Valve spindles in both machines and cylinders were apt to be scored by fine sand, so becoming inefficient and leaky. Cylinders were sometimes returned quite empty, after having been sent away for refilling. Careless users occasionally failed to turn them "off" properly, so that when really needed at short notice later on no gas was immediately available. Of course such difficulties rarely arose in the large base hospitals in Australia, where ample reserve supplies were freely obtainable.

The conclusion, then, is that under field conditions nitrous oxide and oxygen anaesthesia is not worth the trouble which its provision and application involve. To make it freely available imposes a heavy strain on the facilities of supply, handling and transport, while its efficient administration

is quite beyond the capacity of ordinary medical personnel. In base units, however, it has a valuable, if restricted, field of applicability.

Cyclopropane gas, although quite readily available in Australian base hospitals, was not used extensively. Officially regarded as an extravagance, it was not included in the drug scales of units proceeding on active service. As mentioned already, private supplies were taken abroad, and one unit even purchased from regimental funds a quantity of the gas as well as the apparatus required for its administration. However, in the later stages of the war, the special requirements of thoracic and extensive facio-maxillary surgery gave a clear indication for its use on occasion in base areas, whether at home or abroad. In competent hands it is quite safe, despite the likelihood of various cardiac arrhythmias. Thus cyclopropane, in view of its high potency and small bulk, would have been a far better choice than nitrous oxide for the provision of gas anaesthesia under service conditions. Anaesthetists did not accept the view which was official at one time that the manufacture of this gas was not necessary in war time, and in 1942 H. J. Daly published a protest.

INTRAVENOUS ANAESTHESIA

It was not long after the beginning of regular surgical work during this war that the many advantages of intravenous barbiturate anaesthesia, by the use in particular of "Pentothal Sodium", became evident. As time went on this belief was confirmed and strengthened, contrasting markedly with views previously held by responsible authorities. The drawbacks were known, but they were for a time stressed unduly. Risk of methaemoglobinuria in patients who had been taking sulphonamides was reported in the literature, but civil experience had already disposed of any serious objection in this respect. To follow "Pentothal Sodium" with ether sometimes caused respiratory irritation, owing to active pharyngeal reflexes: this could be overcome by caution or by the use of other combinations. Shock, especially associated with anaemia or severe sepsis, was another reason for caution in the use of this agent, but adequate resuscitation often lessened this risk. Questions were also raised about the danger of using "Pentothal" for the surgery of injuries to the face, jaw or neck, or of the throat, in which the airway might become obstructed. Provided the air passages could be kept freely open, as by the use of an endotracheal or pharyngeal tube, "Pentothal" could be safely given, although it is a respiratory depressant.

"Pentothal Sodium" was almost invaluable in battle casualties, and its use increased greatly in the later years of the war. But in very ill or shocked men other agents were commonly employed, and naturally when the thorax was opened and control of lung expansion was necessary, closed endotracheal anaesthesia was indicated. Usually a 5 per cent solution was employed, and even as much as a total of 3 grammes was required for some robust men. Ordinarily much less than this quantity was sufficient. Brief periods of anaesthesia for short procedures, such as

dressings of wounds, could be safely attained by small doses in debilitated subjects. In times of stress "Pentothal", with a much wider scope than spinal analgesia and more ready applicability than general anaesthesia, enabled one skilled anaesthetist to supervise two or even three patients when the rush of work made it necessary for several surgeons to operate in the same or adjacent theatres. Various contrivances were found useful to enable numbers of anaesthetics to be given concurrently, such as a rack holding the syringe, tubing and adapters attached to each patient. Intravenous anaesthesia fitted in very well with the procedure, fairly common in base hospitals, whereby spinal might be in use for one or two patients, the Oxford vaporiser for another, and "Pentothal" for a couple more.

Combined anaesthesia with the use of "Pentothal Sodium" was very successful, the latter being employed either for basal or for supplementary purposes. As an inducing agent it became popular with the patient who had to face multiple operations. It was used quite frequently to supplement inadequate spinal analgesia, and was invaluable as a basis for nitrous oxide and cyclopropane.

Major L. G. Morton reported on 1,000 cases of the use of "Pentothal Sodium" in the 2/4th A.G.H. in Tobruk. There it proved ideal for excision of wounds, removal of foreign bodies, dressing burns, reducing fractures, smaller amputations and numerous other brief procedures. The technique used was to give 1 c.cm. every 5 seconds while the patient counted. When he stopped the amount given was noted and the injection continued at the same rate till half as much again had been given. Further doses of ½ to 1 c.cm. were given as required. The depth of anaesthesia was well indicated by the shallowness of the breathing. As a rule 20 c.cm. of 5 per cent solution would give 20 minutes for a surgeon to work. Preliminary morphine and atropine administration was advisable. This experience was paralleled in other forward areas as time went on. By reason of its portability and ease of administration "Pentothal" proved the ideal anaesthetic for the forward surgical team.

In Tobruk care was taken not to give "Pentothal" in cases in which blood might enter the pharynx and cause laryngeal spasm. An artificial airway was also found to be apt to set up spasm, if inserted too soon. Later experience showed that intubation could safely be carried out with "Pentothal" provided that about 1 gramme of the drug was administered to offset spasm and coughing excited by the introduction of the tube. "Pentothal" alone was successfully used for a number of such cases, but where gas apparatus was available nitrous oxide or cyclopropane was found suitable for further anaesthesia. One advantage of this method in operations involving the jaws was the reduction of vomiting afterwards.

"Cyclonal Sodium" and "Narconumal" were used later on as substitutes on a small scale owing to scarcity of "Pentothal"; but they were less effective and less constant in action. Their low potency invited overdosage, which was disastrous on a few occasions.

LOCAL ANAESTHESIA

Local anaesthesia was little used except for operations on the head, the eye and the nose and throat. Occasionally surgeons considered it suitable for some major operations, but chiefly as an adjunct to intravenous barbiturate administration. In Thailand where supplies of anaesthetics were very scanty, an attempt was made by Captain Van Boxtel to salvage some procaine and adrenalin tablets in which the latter component had deteriorated. Absorption by kaolin removed the adrenalin, presumably toxic, but also some of the procaine. The resultant product, thought unsuitable for spinal injection, was used for local anaesthesia. Later cocaine alone was available for local anaesthesia, and was used for an amputation, but without great success. Other local anaesthetics were successfully used in suitable instances, chiefly for work on the upper limb, the head and neck.

HYPNOSIS

In the River Valley Camp Hospital on Singapore Island the dearth of anaesthetics suggested the use of hypnosis to Lieutenant R. L. H. Sampimon (Royal Netherlands Forces) and Captain M. F. A. Woodruff, A.A.M.C. Twenty-nine patients were subjected to hypnosis successfully for dental and other minor operations.

COMPLICATIONS AND SEQUELS OF ANAESTHESIA

Headache and backache have been mentioned as occurring after spinal anaesthetics. More disturbing was the occurrence of meningeal irritation, a low grade aseptic meningitis setting up meningismus in a certain number. With proved material this did not happen. Sore arms occasionally happened after "Pentothal" but no more serious sequels occurred, such as sloughing or the more unfortunate effects of the drug entering an artery by inadvertent puncture.

Post-anaesthetic vomiting was seen in about the usual proportion of patients who had been given ether. It was seldom severe, and could be largely avoided, if this was important, by the use of other agents and combinations, although it occurred occasionally after spinal analgesia, and but rarely after "Pentothal".

Respiratory complications and sequels were unfortunately common. Though seldom serious they produced discomfort and pain, and added to the cares of post-operative nursing. From the beginning of surgical work in Middle East respiratory complications were frequently experienced. Exact figures cannot be given. In one series of nearly 1,000 cases in a general hospital in the Middle East, as a sequel of anaesthesia over 2 per cent of the men had bronchitis or pneumonia. Greater frequency was noted during the months when dusty winds were common. Most of these respiratory sequels were mild in nature, as indicated in another series of 1,093 cases dealt with at the 2/6th A.G.H. between August and December 1942. The incidence of all respiratory sequels here rose steadily from 3.1 per cent to 8.8 per cent, the average being 5.1 per cent. In this increase the

onset of wintry conditions seems to have been important. A pre-existing tracheitis or bronchitis often flared up, but atelectasis was thought to be much more frequent than usual. Throughout the war a definite proportion of respiratory sequels was observed, greater than might be expected in ordinary civilian practice. One factor of probable importance lies in the nature of the subjects for anaesthesia, who usually required a high concentration of vapour to achieve the state of control and relaxation needed for surgical procedures. Such sequels were noticeably more common when the abdominal wall was involved in operation, but on the other hand they were rare after operations on other regions. In their prevention early movement was found desirable and so deep breathing was encouraged. When any respiratory complication occurred the most practical method of establishing pulmonary drainage was to encourage and even to enforce cough at the cost of immediate discomfort. Even where atelectasis was not present, the aeration of various parts of the lungs was doubtless imperfect, since the expulsion of sticky mucopurulent bronchial secretion usually produced improvement. In the Northern Territory of Australia post-operative pulmonary collapse was noted occasionally. Most cases, but not all, followed the administration of ether under hot weather conditions, in which excessive sweating, combined with impaired ciliary activity, not only favoured the presence of tenacious mucus in the air passages but also hindered its expulsion.

The level of safety and efficiency in the giving of anaesthetics was very commendable throughout the services. Few accidents or fatalities took place. Anaesthetists were able in most cases to satisfy the demands of surgeons and of those even more pungent critics, the soldiers themselves. The appointment of specialist anaesthetists to general hospitals did much to elevate and maintain this standard, reflected in the demands made on duty-officers for anaesthetics, for whom a good deal of supervision and instructional work was called for. Some orderlies attained a high degree of skill in helping in this work. There can be no doubt that the work of specialist anaesthetists under service conditions has enhanced interest and raised standards in anaesthesia.

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PART III

SPECIAL SUBJECTS

CHAPTER 53

MEDICINE AND SURGERY IN CAPTIVITY

THE story of prison camps has always the background of tragedy in defeat, but courage and endeavour may yet win a victory of the spirit. Endeavour of the personal order does much to raise morale and keep it high, even when applied to such *tours de force* as outwitting the enemy or escape. Of a higher order are the selfless enterprises, in which the best in men finds expression. Medical men are privileged in being able to fulfil their normal function of combating disease and alleviating its effects even under conditions of want and oppression. They are thus fortunate in being able to carry out their usual work in prison camps and at the same time to render communal service of high value. From the clinical point of view the important and interesting parts of the story concern unusual conditions encountered and the application of preventive and therapeutic measures with scanty resources. From this emerges something more significant, the peculiar opportunities of the doctor to distil from sordid surroundings a philosophic essence which gives him in the words of Dr K. J. Fagan,

"a high threshold to the pin pricks of life" . . . and a knowledge of "man for what he is—his courage, his cowardice, his limitless generosity, his gross selfishness, his nobility and his utter meanness. And if he tends towards cynicism . . . he is robbed of all bitterness by the memory of the heights to which he has seen some men rise in spite of starvation, of illness and of every degradation which a malignant enemy could put upon them".

This was written of life (and death) in the Japanese working camps in South-Eastern Asia, with which this clinical account is chiefly concerned, but important work was also carried out by the medical services of the A.I.F. in captivity in Italy and Germany. Some details of special medical and surgical conditions have been touched on in other articles in this volume, and general information about the conditions in prison camps will be dealt with elsewhere.

IN CENTRAL EUROPE

Major R. T. Binns, serving with the 2/8th Field Ambulance and Captain E. W. Levings, regimental medical officer of the 2/3rd Anti-tank Regiment, after being captured in Libya, were able to carry on routine medical work under good conditions in Derna. Dysentery broke out in prison camps between Tobruk and Derna, and though only sodium sulphate and chlorodyne were available for treatment the results were good. Subsequently at camp No. 57 at Gruppignano in Italy, Binns and Levings worked as permanent medical officers with Captain J. J. Ryan. At first they could visit the men only at stated parades, but later more freedom was given. Medical supplies were short, but were supplemented by the Red Cross. The chief diseases treated were malaria, contracted in

Gravina and Bari camps in Southern Italy, food deficiencies mainly beriberi arising after capture in Libya, and the usual infectious diseases. Pneumonia and acute nephritis were both common, the latter following tonsillar infection. Mental disorders were rife here, the incidence being six times that seen later in Wolfsberg area in Austria. It was due to the extremely harsh treatment and punishment of prisoners for no special reason, the camp being "a mass of neurosis". Quinine was very scarce here, and supplies were obtained through the Red Cross. In some camps seriously ill men or those needing investigations were sent to an Italian military hospital and thus passed out of the hands of their own medical officers. A good range of dental work was carried out by the Australians according to supplies obtainable: the local Italian standards were not high.

Part of the 2/5th Australian General Hospital, which remained in Greece, was well housed and carried out a great volume of work, until the Allied troops were moved back to Germany. Major Brooke Moore and his staff, reinforced by attached Allied medical officers, were able to cope with all ordinary calls of medical and surgical work. The numbers of regional injuries treated were as follows: head 88, thorax 100, abdomen 39, eye 46, jaw and face 30, fractures 417, joints 132, nerves 153, blood vessels 13, and tissue wounds 658. A great amount of work was handled in the Pathology Department. Dental work carried out by the New Zealand Mobile Dental Unit was of a high grade and included prosthetic and facio-maxillary work and the making of vulcanite artificial eyes.

After it left Athens, the range of work done by this hospital lessened. In Thorn, in Poland, the major surgical work was well done by a German staff in a military hospital. There, frost-bite was occasionally seen, and tuberculosis of bones and joints was not uncommon among the working parties. Salivary calculi were removed from 10 patients; the condition was apparently common in the area. The menace of malnutrition was not absent there; some deaths occurred among men of the several nationalities represented. In this respect, however, the conditions were much better than in the camp in Salonika where numbers of deaths occurred from dietetic deficiencies. In Stalag 383, Bavaria, towards the end of the period, bruising of the skin was noticed frequently and healing of wounds was slow after operation unless vitamin *C* was given. Pine needle tea was used empirically in some camps as a source of ascorbic acid.

Malnutrition was also seen in other prison camps in Germany. Lieut-Colonel L. E. Le Souef reported lack of first class protein and low calorie content of dietaries in some of the camps.

At Oflag 79 the total daily ration to prisoners of war only supplied 1,324 Calories and 7.1 grammes first class animal protein out of a total of 44 grammes protein. Severe reduction of Red Cross reserves of food by the Germans in 1944 and later withdrawal of Red Cross supplements caused serious loss of weight in the men. After five months generalised oedema was noted, more particularly on the ankles, legs and face, and also ascites. Weakness and shortness of breath were also present, and in the absence of any intrinsic cardiac or renal lesion the cause was certainly

nutritional. Lieut-Colonel Le Souef saw many Russians with famine oedema; a German medical officer said he did not understand this disease as no other patients had it, to which Le Soeuf rejoined that it was a very infectious disease called starvation. Among British forces the pinch was felt also. Problems of nutrition were important in the German camps, especially when Red Cross supplements could not be obtained. Men ill with various debilitating diseases such as tuberculosis were an anxiety, and appeals to the camp authorities did not have much success. At Millburg their treatment was very bad. Overcrowding in many of the camps made matters still more difficult. Diphtheria appeared now and then, but fortunately did not spread to any extent.

Lieut-Colonel Le Souef, as senior medical officer, had many battles with German authorities to obtain better conditions. Some of these officers were afraid of higher authority and of breaking regulations. In the winter, the men often suffered from cold. Red Cross blankets were allowed to be used, but only in place of other issues, which were then withdrawn. Food was bettered by the regular arrival of Red Cross parcels, but the Germans sometimes punctured all the tins so that they had to be used at once. The feeding of men with peptic ulcers was difficult: white bread was very difficult to get, and the harsh black bread was not tolerated by them. Racial differences were noticeable in the reactions of patients to food supplements. The Serbs hoarded it, whereas men of other nationalities including the British often threw away the German ration or even Red Cross food, although they were asked to return it if unneeded.

IN JAPANESE PRISON CAMPS

Australian medical officers gathered their experiences of Japanese prison camps in various parts of South-East Asia, and also in the Far East, especially in Japan. In all these in varying degree the spectre of malnutrition menaced members of the Allied Services of all ranks and ages. The worst conditions were found in the camps in Burma and Thailand, particularly those serving the construction of the railway from Moulmein to Bangkok. Lieut-Colonel E. E. Dunlop thus summarises the conditions in the jungle base hospitals from August 1942 to August 1945:

"There were three phases in the tragic Burma-Siam affair:

August 1942 to September 1943: Appalling conditions in railway construction camps which were full of sick. Facilities in jungle base hospitals were negligible, evacuation entirely haphazard, and the death rate deplorable. The Japanese appeared to exult in the havoc caused by their inexorable pressure, and scorned and penalised the sick.

September 1943 to March 1944: A period of concentration of sick in jungle base hospitals leaving a small residue of fitter men along the completed railway line. By immense efforts of organisation of slender medical facilities and mobilisation of small resources of food and money obtained by taxation of all ranks, and negotiations with friendly local inhabitants a remarkable improvement was achieved at the latter end of this period. The Japanese at this stage showed some passive virtues in relaxing pressure on the sick, and afforded a small measure of cooperation.

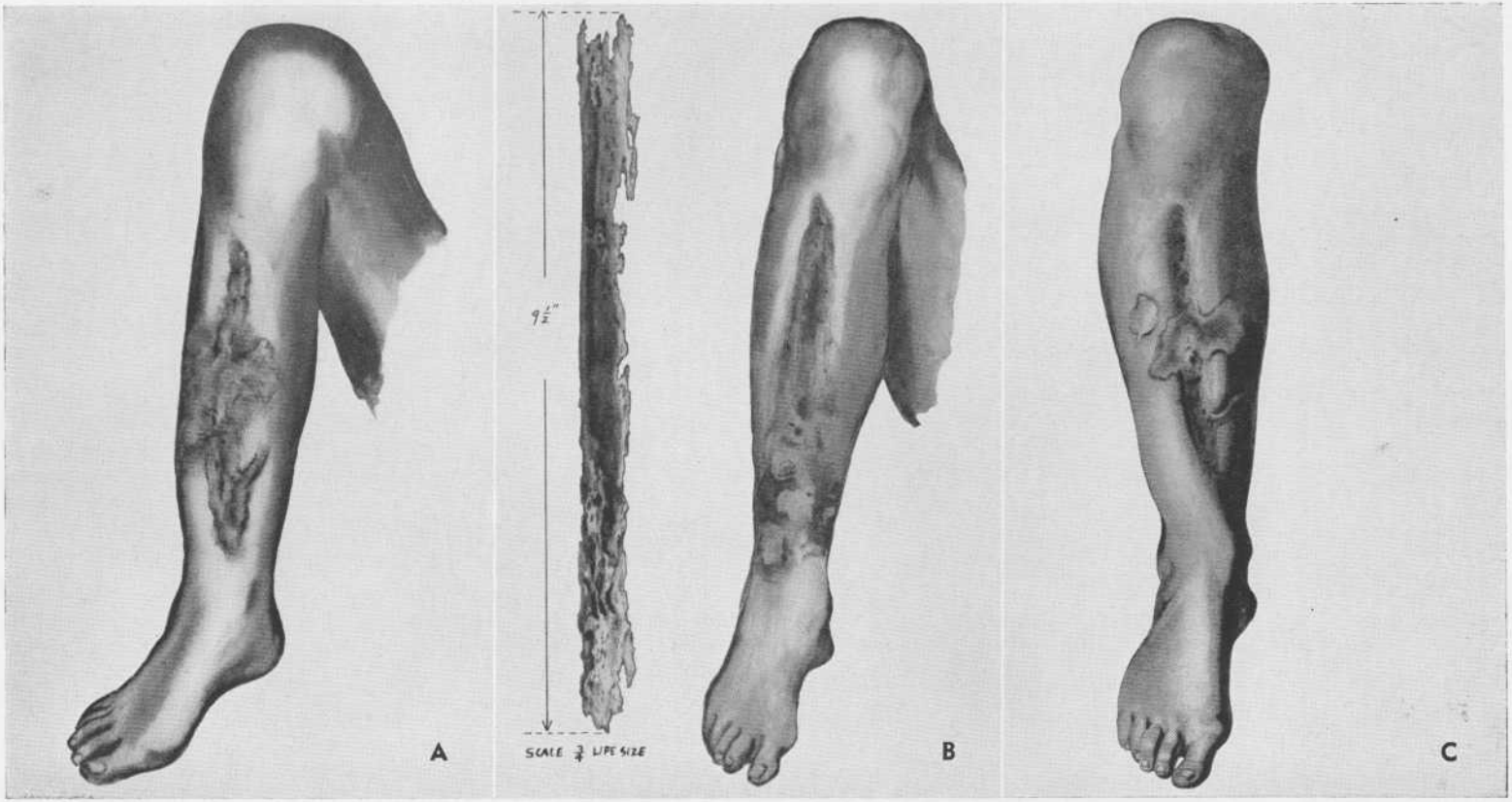
March 1944 to the capitulation in August 1945: Large "face saving" hospitals then contained most of the sick. Many were returned to Singapore, others concentrated at Tamuang and the main mass at Nakom Paton. Though these institutions

were still crude in the extreme they afforded protection from the weather, and some facilities for surgical and specialised centres. Conditions were immeasurably improved, and this undoubtedly related to the changed war situation and allied publicity reflecting knowledge of P.O.W. conditions.

However, there were still small works projects in Burma and Thailand where local conditions reverted to the railway construction pattern."

The improvements hardly won in these areas are well illustrated by the steady fall in the death rates there. Late in 1943, more men died per month in such jungle hospitals as Tarsau and Chungkai than died in over a year at the huge Nakom Paton. Yet at Chungkai the deaths fell from 257 in October 1943 to 135 in December, to 143 in the first three months of 1944, and to 37 in the second quarter. It should be noted that Nakom Paton, built as a "show place" to hold 10,000 patients and reflecting the sensitivity of the Japanese to their adverse progress in the war, was only commenced in March 1944, long after the completion of the Burma-Thailand railway, on which the lives of 15,000 Allied soldiers and countless coolies were sacrificed. In the jungle camps were hospitals, so-called, where the medical officers practised the best medicine and surgery they could under the most intense difficulties. Under the direction of officers of the R.A.M.C., I.M.S. and A.A.M.C. and other Allied services, these primitive base hospitals were established, some of them such as Tarsau and Chungkai, holding up to 2,500 patients. In Java and Borneo and other parts of the Netherlands East Indies similar struggles against serious disease and malnutrition went on, with even sterner struggles to obtain a bare minimum of medical supplies. As Dunlop has said: "The fruits of experience as prisoners of war in Japanese hands. though abundant, were exceedingly bitter". Nevertheless these fruits were gathered, and the experience gained was used in improving the meagre methods to hand. Clinical acumen was sharpened in the absence of special methods in all but a very few settled areas, and resource and ingenuity devised extemporisations which made possible some approach to reasonable standards of medical practice. Even ideal hospital conditions could not have prevented the heavy weighting of the scale against the patients, especially those who had been in working parties, and in particular during the earlier years when the treatment of prisoners was harsh in the extreme.

Men working on railway construction toiled up to sixteen hours a day, often leaving and returning to their hovels in the dark, with their remnants of clothing soaked in the monsoonal rains. Except for an occasional spasmodic hygienic gesture of inoculation against cholera or dysentery no attempt was made by the Japanese to maintain any principles of prevention of disease. Expendable supplies were farcical. Dunlop describes a typical monthly issue for a thousand men in a railway working camp, mostly sick, as consisting of "6 to 12 bandages, a small piece of gauze or cloth, 1 or 2 ounces of spirit or iodine solution, and a few dozen assorted tablets of dubious value". No issues were made of non-expendables. Even the sick were often forced to work regardless of their condition, and worse, suffered frequent persecution, by stoppage of pay,

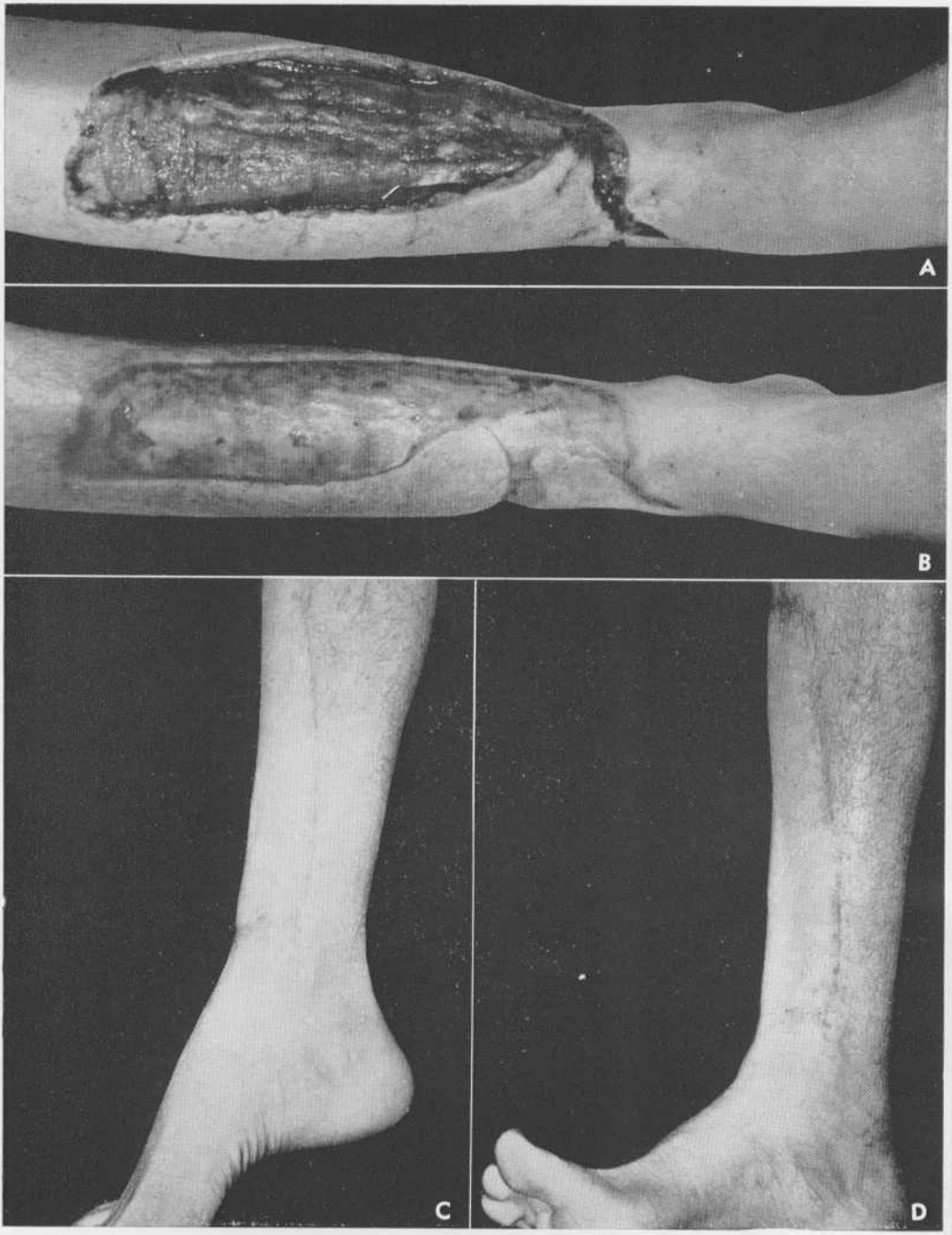


(Drawn by A. G. Old)

Deep tropical ulcer with sinuses, June 1943.

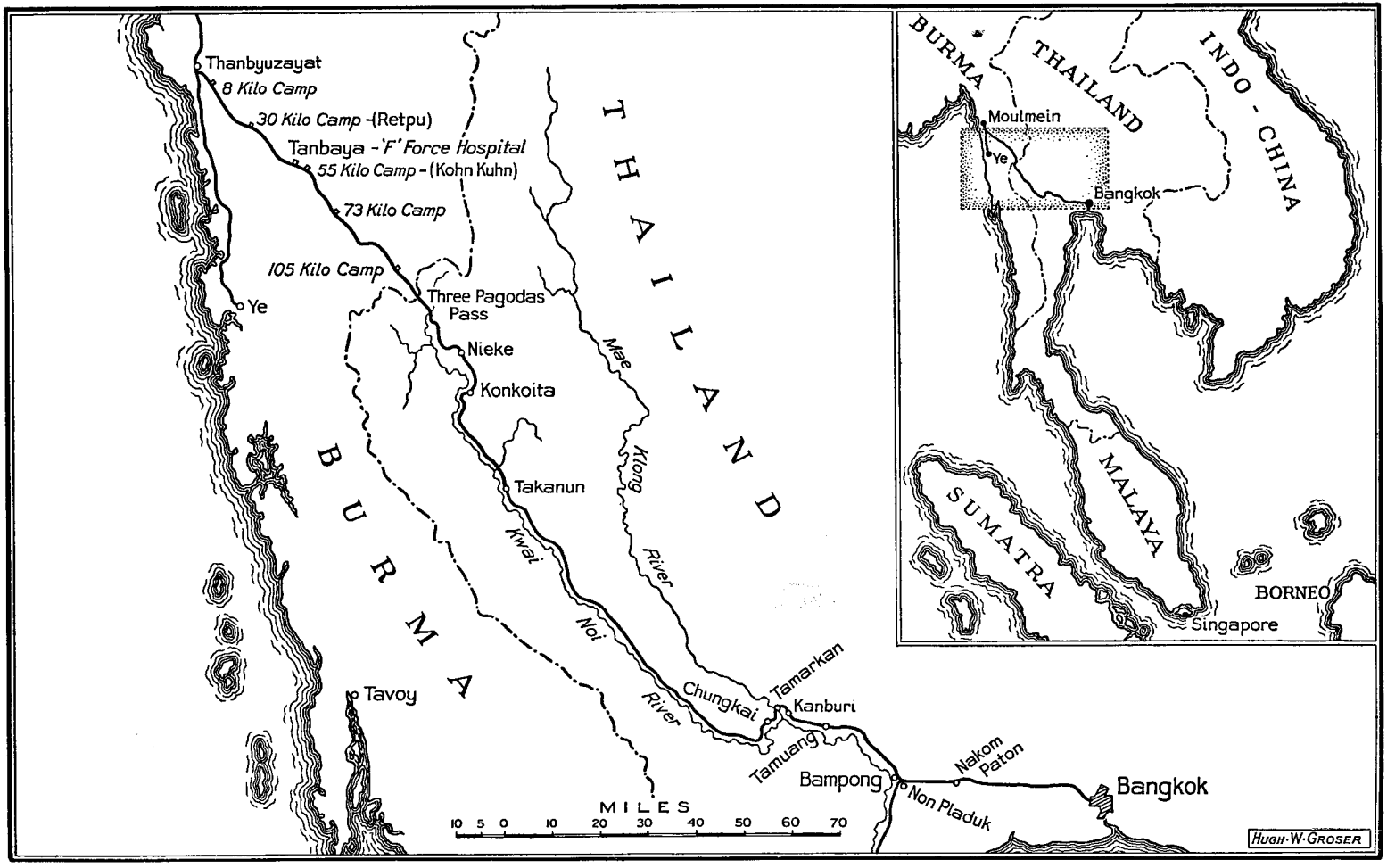
Condition in November 1943 after removal of sequestrum 9½" long.

Almost healed, February 1944.



Primary or early grafting of wounds with extensive skin loss.

(a) Extensive skin loss on the leg with some tendon exposure.
(b) Wound healed by split skin graft applied within a few days of injury. The bare tendons were covered by a local flap. The result in the grafted area is not final, but is regarded as a temporary dressing to effect healing and prevent scar formation.
(c) and (d) Final result after replacement by a migrated flap from the abdomen. The tendons are now freely mobile.



Burma-Thailand Railway

reduction of rations and employment on work which accentuated their particular disabilities. It was not uncommon for men with ulcerated feet to be placed on "light work" which involved clearing rock in jagged rock cuttings. When men were sent to hospital the lorries or barges for their transport often arrived bearing both living and dead. Even worse maltreatment sacrificed almost the whole of "B" Force and "E" Force sent from Singapore to Sandakan, including 2,000 Australians. In the Changi area conditions were less unfavourable, but even in this and other base areas a never-ending fight was waged to obtain supplies of food and drugs, or even any consideration for the sick. Extemporisations perhaps reached their highest point of ingenuity in these more settled hospitals, and combined efforts of all British, Australian and Allied forces obtained supplements of diet which lowered the risk and to some extent the incidence of nutritional disease. By careful buying of extra food and some help from the Red Cross it was even found possible in Changi at the end of 1942 to maintain a reserve of food.

MALNUTRITION

This is dealt with in detail in a special section, where the serial appearance of different groups of symptoms of deficiency is described. No clear-cut pictures of single deficiencies can be expected in such conditions of virtual starvation. Multiple deficiencies were therefore common, such as simultaneous insufficiency of protein and various vitamins, in particular, components of the *B* complex. Dunlop reported from Thailand that in spite of all possible efforts lesions of the mouth and scrotum tended to be persistent, and were forerunners of more serious troubles, such as loss of acuteness of vision. The importance of the lack of the ordinary components of diet, especially protein, was far reaching. Necrotic lesions like the tropical ulcers flourished in these circumstances. The association of spreading gangrene on grossly oedematous areas, often seen in "F" Force in Thailand, was nearly always fatal. "F" Force suffered bad treatment in every way and unfortunately supplied very many instances of nutritional oedema. Its medical officers, notably Major Bruce Hunt, not only resisted courageously the inhuman treatment of the sick, but did their best to alleviate their condition by whatever supplements to diet were possible. Hunt also produced a complete brochure on his observations on beriberi and its relationship to the cardiac affections common among these men.

The supplements to diet achieved in various areas were of two kinds, those building up the chief dietary components, and those supplying accessory vitamins. In Changi soya bean, pigeon pea, red palm oil, dried whitebait and other fish were bought while they were obtainable. In Thailand the local ducks performed an important function in supplying eggs. Fisher found that 2 or 3 eggs a day would arrest the downward course of a patient with pellagra. Hazelton also, at Nakom Paton, by increasing this accessory ration to 8 or 10 eggs per day, produced rapid improvement. Glyn White described how at Changi plants were not only grown to produce drugs, but also as an addition to diet.

The dietary problem was realised as serious immediately after Singapore fell. Fortunately a number of experts in nutrition were available for advice and guidance in Changi and an Allied Nutritional Advisory Committee was formed. This body examined the diet provided by the Japanese, together with the supplements available. The likely deficiencies were known, as were also the most promising local sources of necessary food constituents. Recent analytical tables were available, and experimentation began on vitamin supplements. The well-defined syndromes due to deficiency states did not always fit neatly into the dietary pattern, but a great amount of clinical material was gathered and records kept where possible of dissections of dietaries. In the sections on malnutrition and ophthalmology these symptom-complexes are described and an attempt which can only be partial, has been made to relate them to deficiencies of protein, fat, mineral salts and vitamins.

Research enterprises were set up to investigate local facilities, and resulted in the evolution of useful processes for preparing grass extract, and yeast, and later, when the carefully guarded supplies of "Marmite" were running out, a substitute for "Marmite". Rice polishings were officially supplied after a time, and were believed to contain the whole *B* vitamin complex. Extracts of greenstuff were valued because of their rich riboflavin content, green gram, a local vegetable, peanuts and green leaves were thought worth trial. A number of workers skilled and interested in the subject investigated the methods of extraction, and finally a grass soup was produced which was thought to be a source of vitamin *B*2 complex. This was used therapeutically as described elsewhere. In Thailand wild pumpkin leaves were used prophylactically.

Experiments were also carried out on the production of yeast for therapeutic purposes. In Changi cultures could be obtained, and, although the question of the propriety of using sugar as a basis for a culture medium was raised, the work went on at a yeast centre which made and distributed the yeast. The range of research on yeast was considerable, covering the effects of hops as a bacterial inhibitant, variation of the pH, and the value of rice and many other substances as a culture medium. Experimental work on fowls in an attempt to assess vitamin *B*1 in yeast was unsuccessful. One of the most important observations was that rice polishings made a good substitute for flour, in yeast cultures, at least until supplies ceased. The rice polishings also saved some sugar.

Careful rules were drawn up governing the use of these dietary supplements, and medical priorities were established. Wherever extras could be bought care was exercised in the expending of the money, though of course private trading went on to some extent.

Dietary records were kept wherever possible. Many of these, especially in Changi, are amazingly well kept and detailed, including analytical data on foodstuffs. These were used as bargaining points with the Japanese on many occasions, though with scant success. The intrinsic scientific record of these alone is considerable, but even more important was the

value to the force at the time; they were an earnest of the tireless keenness of the medical services.

An excellent summary of the dietetic deficiencies has been made by A. T. H. Marsden. Fat was at all times grossly deficient, protein too was nearly always most inadequate, first class protein being specially lacking. At Nakom Paton he estimated the actual amount of protein absorbed, as judged by excretion rates, to average only 32 grammes. This falls below even the bare minimum of mixed protein considered sufficient to maintain nitrogen balance. Vitamin *B*1 was deficient for the first two years, but Marsden personally saw no clinical evidence of its deficiency thereafter. *B*2 complex deficiency in one form or other persisted throughout the whole period. The clear cut syndromes described in the section on malnutrition represented phases chiefly in *B*2 deficiency by the appearance of "classic" signs of withdrawal. There can be no doubt that the general dietetic stringencies produced generally low standards of health and resistance and prejudiced survival. Marsden found evidence of increased susceptibility to disease, and to secondary infections. He also noted slowness in overcoming infection, and alteration in the clinical appearances of disease. The latter were evidenced by such frequent happenings as chronic infection of the prostate and of bone by low grade pyogenic organisms which imitated gonococcal and tuberculous lesions. The influence of fatigue on resistance to disease expressed itself chiefly by a greater liability to relapse of infections. These observations were made from the pathological viewpoint and are amply confirmed by many medical officers whose judgments were made on clinical evidence.

One of the most serious nutritional disturbances of prison life was the "deficiency amblyopia" which is fully described in the section on ophthalmology. Corneal ulcers were also seen in some areas, characterised by an alarmingly rapid development, but in those places where adequate supplies and facilities existed surprisingly good results were obtained. In the prison camps in Japan the conditions in camps of South-East Asia were duplicated. In some of them severe malnutrition was common, and diarrhoeal diseases were prevalent and a menace to life. Food was poor and insufficient, drugs were obtainable only with great difficulty and always in inadequate amounts, and instruments were equally scanty.

TROPICAL DISEASES

Malaria was almost universal in the railway camps. Clothing was entirely inadequate, so was accommodation; mosquito nets and other requirements for personal protection were virtually unobtainable, and no mosquito control was possible. In Changi some degree of control was possible, and entomological surveys were carried out, but the Japanese hindered rather than helped these efforts, and interposed a cumbrous administrative system by which official assent to the necessary activities was difficult to obtain. The debilitated state of troops made them a ready prey to recurrent malaria. Benign tertian was more frequently seen than

malignant tertian, and the number of attacks of the former rose to as high a figure of 20 attacks in a year. Cerebral malaria was not infrequent and was treated with difficulty. Quinine, always difficult to get, was not obtainable in ampoules, and sterile solutions of any forms available were prepared and used. Medical officers found that malaria often imposed the last burden on sick men: Lieut-Colonel Huston, R.A.M.C., in reporting on "F" Force in 1943 noted the great deterioration caused by malaria in patients with other diseases, and stated that it "often heralded the end of the struggle".

In "F" Force in Tanbaya, one of the clinical features noticed was a high degree of resistance to quinine. Fever often could not be controlled under six to eight days, and relapses occurred on the tenth or eleventh days of treatment in men still taking quinine. This phenomenon has been referred to in the section on malaria: it seems likely that resistance to treatment in this instance was chiefly related to poor absorption. This is borne out by the observation that in the same areas cerebral malaria responded to parenterally administered quinine. It is surprising that though occasionally haemoglobinuria was seen, blackwater fever did not occur at this time, since in February 1943 at Chungkai alone the rate of new and relapsing malaria rose to 800-900 per month: 70 per cent of the affected men had an enlarged spleen. If any proof of the value of antimalarial drugs had been required, it was amply given when on the arrival of the liberation forces atebrin was fully distributed and used with excellent results.

Cholera was the most deadly of all the tropical diseases encountered. It is described in a special section. Lieut-Colonel Huston's report on "F" Force showed that the immediate mortality among 1,300 men attacked was 30 per cent. The true ultimate mortality was hard to estimate with so many other causes at work; it may have even reached 80 or 90 per cent in places, and caused about half the deaths in the force. Major R. H. Stevens, in journeying from Singapore to Kami Sonkurai, Thailand, commented on the wretched accommodation for the luckless patients, often housed perforce under leaking tent flys placed on the rafters of a hut. The ingenious methods of countering dehydration by using hastily prepared solutions of salt in creek water have been already described. In a very severe epidemic at Hintok camp where the camp site was a noisome morass in the jungle, stills were hastily improvised from stolen petrol piping surrounded by bamboo jackets fed by spring water led in by bamboo pipes. Sixty-three men died out of 150 infected, but lives were saved even in the algid stage of the disease. The skill and courage of all concerned in such work had their reward when the cold shrunken hands of a corpse-like figure became once more human, and with returning circulation gave hope of another success in the midst of mud and desolation.

Three crude stills produced 120 pints of distilled water daily which was used for saline solutions administered by infusion sets improvised from stethoscope tubing, tins and saki bottles. As much as 20 pints of saline was given in 24 hours. Whether inoculation of cholera vaccine was

effective or not is hard to judge, in his own experience Hunt found it of definite protective value: the Japanese had great faith in it, but inconsistently neglected to provide even rudimentary hygiene in the camps. That this factor was important is shown by the observation of Lieut-Colonel Pemberton, R.A.M.C., that men in bivouac shelters other than tents were more susceptible to infection by cholera.

Dysentery needs no special mention here: it is covered in the appropriate section. The incidence at times was very heavy. Glyn White and Bruce Hunt reporting on experiences in Changi showed that, initially flyborne, an epidemic outbreak occurring there was spread also by carriers returned to their lines. Enough sulphapyridine was available to prove the great value of this group of drugs, but there was no hope of adequately controlling residual infections under existing conditions.

The percentages of types of dysentery, and even of amoebic infections, are impossible to assess accurately. In some areas acute amoebic infections were common. Hunt considered that 70-80 per cent were amoebic at Kanburi. Subsequent studies have shown that infection was almost universal in these regions. The value of antidysenteric vaccine is not easy to assess. H. H. Eddey thought that its use in "E" Force in Borneo helped to prevent outbreaks in 1943-1944 and quoted the low incidence in Kuching, where inoculation was used and where no major outbreak occurred till later when general conditions were much worse.

Amoebic infections were severe and frequent. The special experience in Burma and Thailand has shown once again how serious and destructive the uncontrolled disease may be, but nevertheless that a degree of natural immunity may be gained, and that cure may take place even in the absence of specific drugs, especially if adequate rest of the affected part of the bowel is secured by surgical drainage. This is described below with other surgical work. Mention must be made too of the simply devised proctoscopes used for diagnosis and control of treatment. These were made of tin, with inbent edges, and by reflecting sunlight from a mirror good vision was obtained as far as the three rectal valves. Strictures in the healing stages were often seen and usually responded to stretching with graduated bamboo dilators. Regular proctoscopic clinics were conducted at 55-kilo camp Burma by Lieut-Colonel Coates, and at Nakom Paton by the physicians. At Chungkai more elaborate sigmoidoscopes were devised with an obturator and means for inflation.

Hepatic abscesses were sometimes seen, but the number was very small in proportion to the number of amoebic infections. Only 8 patients required operation out of Coates and Dunlops' series of 1,346 cases. One patient died of cerebellar abscess.

The surgical treatment of amoebiasis was of outstanding interest and value. That this was required was due to the greater severity of the disease in its attack on debilitated men, and to the almost total lack of specific drugs. Emetine was scarce and precious; an additional 150 grains were made from ipecacuanha by Captain Van Boxtel, an expert Dutch chemist acting as a volunteer medical orderly. The immediate effect of

emetine was often dramatic; unfortunately there was little to use. Carbasone and other drugs were later occasionally obtainable from Red Cross sources.

The early success gained by Coates in the performance of ileostomy on a man very ill with intractable amoebic dysentery led to further resort to surgery. The disease being confined to the colon, ileostomy provided adequate rest for the damaged bowel, and colostomy was found to be dangerous, as amoebic infection of the skin ensued. Cutaneous amoebiasis was occasionally seen after caecostomy and appendicostomy also. Coates established ileostomy as a sound procedure which alleviated the condition by relieving tenesmus and gaseous distension and by removing the risk of perforation. Other surgeons independently found appendicostomy and caecostomy of great value. In Dunlop's series of 12 appendicostomies and 2 caecostomies all patients recovered fair health, and only one required ileostomy. He concluded that these procedures were safe and effective for less severe infections, and that ileostomy gave excellent results where more serious damage had occurred, and offered the surest method of arresting the disease.

The indications for operation were gross deterioration of condition due to incessant flux of mucus and blood, tenesmus, pain and loss of rest, and also long standing damage of the colon without relief, especially the occurrence of stricture. The use of bowel lavage did not seem to be so important as physiological rest. There was risk of severe amoebic infection of the abdominal wall with these operations, but ileostomy was in this regard virtually safe. Emetine was desirable for post-operative use, but not imperative. In any case it was usually unobtainable in adequate amounts, if at all. A small incision was used for ileostomy, with some provision for muscular valvular action if possible. The site chosen was about eighteen inches from the ileo-caecal junction so as to allow easy anastomosis later. The bowel was divided and a tube fixed in each end. Closure was carried out successfully in a few of the earlier cases; as a rule, however, this was left to be done after the liberation of the force. Fourteen men were submitted to ileostomy in Nakom Paton; three died in a hopeless toxic state, the remainder regained reasonable health, some of them resuming a remarkably active life. A Dutch metal water-bottle was altered to make an ileostomy bottle for the first patient, and proved then and afterwards to be very suitable.

Hookworm appeared in its severer forms in some areas; there can be little doubt it was a significant factor in producing anaemia and debility. Ground itch was a prominent feature in some acute attacks. The subject is further discussed in the appropriate section. Affections of the skin were of course extremely common: the most important were those due to infections arising on sites of trauma. Scabies was very common, so too were impetiginous sores due to this and other causes. In the Changi area, derris root solution was used for scabies. The patient was thoroughly scrubbed and derris root solution was applied all over and allowed to dry. This was repeated for three or four days and usually produced a cure.

The plant grew in the neighbourhood of Changi and its roots were used to make a solution by grinding up in boiling water; this was stable for several days. No soap was available in Burma and little sulphur. In Thailand sulphur could be obtained, and at Nakom Paton soap also. Soap was manufactured in Changi from available oils and fats and alkalis obtained from wood ash. Purulent skin lesions responded well to sulphonamides when these could be obtained and spared, which was seldom. Even small doses such as one gramme a day produced a favourable result. It may here be remarked that the relation between septic skin lesions and the prevalence of insect pests not only caused great concern in the jungle camps but also inspired action. Disinfestation was undertaken, ingenious extemporisations being used and in some areas huts were periodically practically dismantled and their components flamed. In this way pests were largely controlled in the more settled areas.

TROPICAL ULCER

By far the most important lesion of the skin was the "tropical ulcer" which under the bad prevailing conditions soon ceased to be a skin affection and penetrated deeply into the soft tissues, invading even bone. Its background was undoubtedly malnutrition, and its excitant trauma of some kind. Ulcers formed particularly on the parts of the body most exposed to injury, such as the ankle, front of the leg, dorsum of the foot, buttocks, back, crests of the ilium, trochanters, skin folds, and flexures. Ulcers often developed rapidly from small beginnings, whether from a scratch on bamboo or rock, or from the multiple small lesions due to scratching the itchy skin of scabies. A few patients succumbed to a terrible multiplication of necrotic ulcers all over the body. Patients with debilitating diseases, such as dysentery or malaria, often had their skin break down by lying on unyielding bamboo beds; even sleeping on one side or the other might produce sores on the trochanteric regions in the same way. Multiple ulcers on the feet were common also, and pemphigoid lesions appeared on the legs, only too often to lead to severe and even fatal ulceration, especially if oedema was present. Little reaction was seen in many of these ulcers, which by a necrotising process invaded the deeper tissues. Captain F. J. Cahill, A.A.M.C., wrote a special report in March 1944 which describes well this condition as seen by only too many medical officers. He emphasised the speed with which a small abrasion of the skin became infected and within 48 hours would appear as a sloughing ulcer involving fascial and muscular structures. Sometimes a line of demarcation would be formed, with an associated zone of tissue reaction. In debilitated patients no such reaction occurred, and death from toxaemia was frequent. The pain was considerable, and sometimes intolerable, of a constant burning type, preventing sleep. Muscular spasm was an important associated feature, leading not infrequently to contractures perpetuating flexion of the knee or dropped foot. Where bone was near the surface, as in the front of the leg, the periosteum soon became necrotic, and the exposed bone eroded. Sequestration of flakes of bone or even large parts of a

diaphysis was not uncommon. Favourable progress sometimes took place with granulation of the deeper tissues, but, even if bony sequestra separated, healing was very slow. The growth of skin was exceedingly slow: an ulcer not much larger than an inch in diameter would take many weeks to close. Pus formation did not occur in the most virulent ulcers, but in others it tracked along tissue planes for considerable distances, calling for incision and drainage. Cahill remarked particularly on the rapid spread of tropical ulcers if the patient fell ill with malaria, or dysentery, when physical deterioration and death were not infrequent. Beriberi was a frequent complicating factor also, and oedema whether due to protein or vitamin deficiency hastened the extension of ulcers. One common and very serious combination was the infection of a subcutaneous bleb on the dorsum of an oedematous foot. The skin and deeper tissues disappeared, leaving a foul ulcer, and the patient rapidly died from toxic absorption. Secondary haemorrhage was fortunately rare, but very dangerous.

There was no question of the importance of the nutritional factor in the production and extension of these ulcers, but unfortunately it was largely outside the control of the medical services. Treatment was therefore limited to local measures; it was never certain if the unfortunate patient would be allowed to rest, or be forced out to work. It was in those camps where tropical ulcers appeared in their most severe form, that drugs and dressings were exceedingly scanty. For example, four hundred men in all needed treatment in Tanbaya, and the quantities of antiseptics, sulphanilamide or even salt were totally inadequate. Water sterilisation powder in solution was used as a dressing, but water too was limited in supply. Sulphanilamide could be given only a restricted trial, but Cahill obtained excellent results, and thought that further supplies would have lowered the death rate substantially. Dunlop, however, found the sulphonamides disappointing, ineffective locally, and not available in sufficient quantity for adequate oral use. An attempt was made to assess the value of saturation with vitamin *C*; 300 mgm. of vitamin *C* with an unknown amount of vitamin *A* in capsules was administered to six severely ill men for six days, but no improvement was seen. Later rice polishings were available and a definite improvement was noted, as well as a halt in the incidence of fresh ulcers. Medical officers felt that this supplement of the *B* complex was of assistance. Excision and curettage was a conservative measure which gave good results, especially when combined with application of phenol and iodoform. Dunlop at Tarsau and Chungkai reported that nearly 1,000 men in these camps suffered from severe ulcers, about 200 having exposure of bone. The method just described was found to merit becoming an established procedure, and when supplies of drugs permitted its regular use amputation was seldom necessary. In more settled hospital camps, this could be followed by skin grafting, and healing in a month was often obtained. Iodoform, bought from the Thais, was very useful as a local application. Naturally such treatment was not obtainable in all places.

In spite of all endeavour the only alternative left in the severest ulcers was amputation. Some of the surgical considerations have been dealt with in the section on amputations. Decision to amputate was based on the following conditions: spreading acute ulcer not responding to local treatment; extensive exposure of bone with suppuration and signs of deterioration from sloughing; septic absorption and pain. As pointed out elsewhere, a low level was selected for amputation where possible, but later experience showed that the risks entailed were too great. The site of election was often involved in the necrotic process, and much better results were obtained by amputating through the middle of the thigh. This minimised the danger of sloughing of flaps and secondary haemorrhage. In the 55-kilo camp, Coates performed 120 amputations under spinal anaesthesia with cocaine.

At Tanbaya 420 patients were treated for "tropical ulcer"; of these 250 died (60 per cent). Two-thirds of the deaths were associated with the onset of intercurrent disease, in particular dysentery, beriberi, and malaria. Amputation was performed on 40 patients with no immediate deaths. Three months later, however, only four of these patients were still alive. Cahill comments on "the amazing cheerfulness and fortitude of the patients in the ulcer wards—and the steadfast devotion to duty of so many of the workers" in these wards.

Coates had a remarkable experience with tropical ulcers, in Singapore, Sumatra, Burma, Thailand and finally in the huge camp at Nakom Paton. His observations show clearly the important part played by malnutrition, hardship and illness in producing and perpetuating severe ulcers and causing death. Under more favourable conditions the indolent ulcer responded well to light curettage and dusting with iodoform powder; adequate rest was essential. On the Burma-Thailand railway the severe forms have already been described. At 55-kilo camp where starvation, neglect and harsh treatment by the Japanese had lowered the resistance of the men and of their damaged tissues to a minimum, "laudable pus" was welcomed. Hot rice poultices were used in an attempt to promote inflammation, and Coates comments on the relative relief felt when the pain of this inflammatory process replaced the intolerable anguish of ischaemia and necrosis. No bacteriological investigation was possible, of course, but the condition suggests a symbiotic infection allied to a failure to resist. Nothing resembling gas gangrene was seen.

An ulcerous process involving tendons was also seen. In one camp over 60 patients were so affected. Great pain was a feature here too, but surprisingly good results followed excision of affected muscles and tendons. Even removal of the *tendo Achillis* gave excellent functional results in many instances.

In Nakom Paton, where more deliberate surgery was possible curettage, mentioned above, gave relief to many hundreds of men, who often had perforce to endure it without anaesthetic. The problem here was largely a residual one, as fresh infections in the inmates of this more favourably situated and organised camp were very rare. Sequestrectomy was per-

formed when required accompanied by wide "saucering" procedures, also skin grafting and correction of deformities. A wider application of amputation was possible also, even though many men submitted to operation had gross nutritional and chronic infective stages. Even so, the immediate mortality was only 10 per cent and half the men survived further ordeals of illness often with the help of blood transfusion. On liberation 170 men with amputated limbs, including two with double amputations, were alive and reasonably well, all provided with useful artificial limbs.

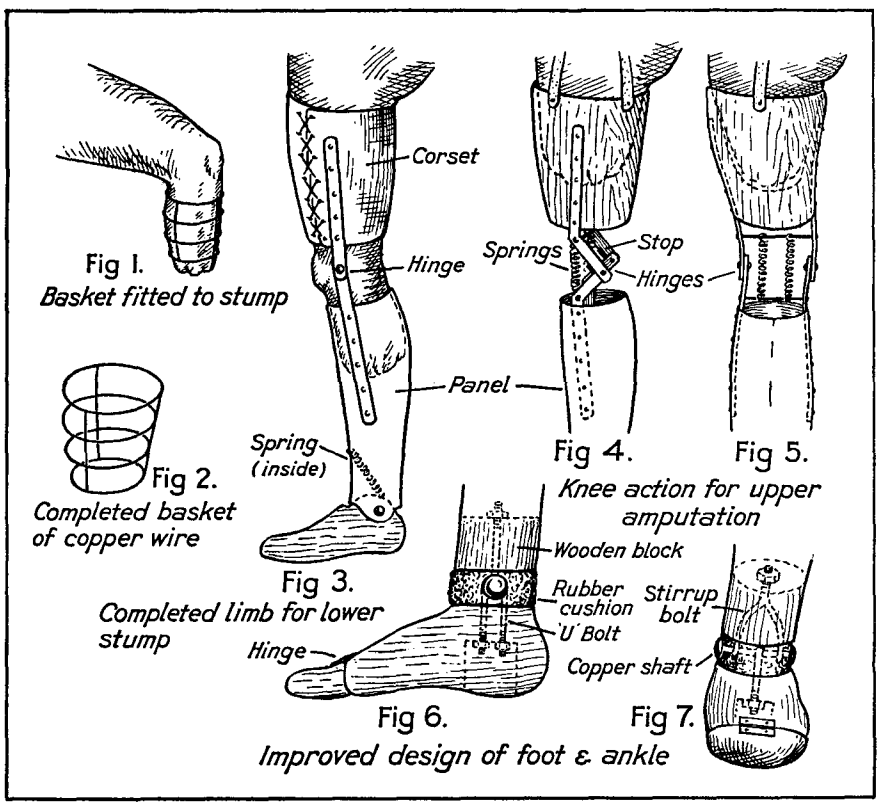
Many devices were extemporised in this hospital for the treatment of tropical ulcers, including irrigating cans, portable charcoal sterilisers, dressing instruments allowing a "non-touch" technique, and suspension apparatus to prevent contractures and increase comfort.

ARTIFICIAL LIMBS

The necessity for providing men with artificial limbs after amputation inspired teams in a number of hospitals to produce highly efficient prostheses. In March 1943 a conference of officers representing medical, ordnance and engineering services was held at Changi to start a workshop for artificial limbs, and this was established under Warrant Officer A. H. Purdon. The problems of the short and the long stump were tackled, and with the use of a basket of copper wire to make a mould of the stump, in default of plaster, a wooden mould was carved out of rubber wood. Steel of 3/64 inch thickness from scrapped motor bodies was used by a panel beater to make a limb socket to this mould, the welding being done by ordnance personnel on a plant made by the engineers. Hinges were made from wrought iron from splints, and a corset from fire hose. Both peg leg and foot-bearing types of limb were built and proved very successful. The foot was made with 20 degrees of movement controlled by a spring in tension. Springs were fitted to ensure the return of the limb to the straight position after bending at the hinge, and the hinge was stabilised for walking by placing its axis one and a quarter inches in line and to the rear of the true axis of the knee. Hyperextension was prevented by a stop welded to the top of the hinge. Complete with boot, the limb weighed about eight and a half pounds. Many experiments were carried out on varieties of brace, and adjustments to allow for tissue wasting and to provide full comfort required time and attention. Improvements in the ankle joint and in other details were also made. With the material available it was not found possible to lighten the limbs much, but aluminium "acquired" from various sources was used to make the foot piece lighter. These ambitious efforts were very successful: it is remarkable that, even with the advantage of having skilled men available, such mechanically elaborate workmanship was possible.

Previous essays in temporary limbs had been made by Private Russell (instrument repairer) and Private Glynn (bootmaker). These were made from Thomas knee splints and leather covering of ambulance seats, and served their purpose well.

In other camps, bamboo pylons were made with moulded top fittings, and a simple base. More elaborate models incorporated a carved foot piece with an articulation. Serial models were constructed in several camp hospitals, the ubiquitous bamboo being used. The Burma, Chungkai and Tarsau models were all made on the same basic design. Others of more ambitious type were made at Nakom Paton, where Major F. A. Woods supervised the work, which he had begun in Tarsau camp. Here, as in other camps where practically nothing existed save what was brought there by the prisoners themselves or grew from the soil, every scrap of any material was precious. A special appeal was made to the men to save and give all manner of things, such as scraps of cloth, leather, rubber, string, wire, nails, screws, tins, solder *et cetera*. These were used in extemporisations of all kinds, amongst others, artificial limbs. To the making of these limbs went timber, leather cured from hides, thread from unravelled packs, odd bits of iron and rubber. The moral effect of helping the mutilated men to walk can hardly be estimated.



Artificial limbs made in Changi camp

OTHER SURGICAL AND SPECIAL WORK

Besides the special work done to relieve the sufferers from amoebiasis and tropical ulcer, a wide range of surgical work was carried out in the larger camp hospitals so far as conditions permitted, especially Changi and Nakom Paton.

During the early months after capitulation, there were many difficulties in surgical work at Changi, even though reasonably suitable buildings were available. Sterilisation of instruments, dressings and gowns was difficult. The autoclave used liquid fuel which was strictly rationed, but later a large autoclave in the British hospital was connected with the cookhouse steam plant. A number of small electric sterilisers were held in stock, and these were most useful when power was later provided. A combined operating theatre was jointly used by British and Australian surgeons with their own staffs. After a time a separate theatre was established for septic cases. This was necessary, for the patients wounded in action needed review and further treatment after the inevitable confusion of the moves to the sites prescribed by the Japanese. Indeed it was due to astute organisation of Lieut-Colonel Glyn White and others that a great deal more ambulance transport was employed in the transfer of the sick and wounded than their captors allotted. Only for this, the lot of these men would have been much worse, and the supplies brought into Changi would have been much more restricted.

A review of all battle casualties was carried out; this involved the examination of 1,100 patients. The unfavourable conditions at Changi just after the capitulation produced a very poor surgical environment. Flies appeared in myriads and no dressings could safely be done except under nets. Here, as in other more insanitary camps, fly-blowing of wounds occurred, but the presence of maggots did not improve the state of suppurating wounds, contrary to findings elsewhere. This review of the wounded revealed one feature of interest—a considerable number of nerve lesions of which 53 were found. These were followed up; 40 per cent recovered, and about half as many made partial recoveries. Some maxillo-facial surgery was carried out on the wounded by Lieut-Colonel Middleton, R.A.M.C., and Lieut-Colonel Osborn, A.A.M.C., using special instruments locally made in the camp area.

Surgical gloves soon disappeared owing to wear and tear and deterioration. Osborn thought that infection of wounds occurred more frequently thereafter. Most ordinary necessary surgery was done there with good results, though the surgical work done in Changi dwindled by 1943, owing to the transfer of men to other camps.

A feature of the abdominal work was the amount of gastric surgery done. This was due to the unsatisfactory results often obtained from the medical treatment of gastric and duodenal ulcer. The general diet was unsuitable for patients with peptic ulcer, suitable supplements and variants were almost impossible to obtain, and drugs were scarce. A series of 44 men proven to have peptic ulcer was studied carefully by Lieut-Colonel Cotter Harvey and Lieut-Colonel Bye in the medical wards. Twenty-one

of these men were submitted to operation. Lieut-Colonel Osborn performed posterior gastroenterostomy in fourteen cases either in Changi hospital or later in Kranji, and in five cases partial gastrectomy. In addition eight operations for acute perforation were performed. This work was not lightly undertaken, but by 1943 it was evident from the good results obtained that surgical measures alone would give relief. This opinion was justified by the unusually florid nature of the ulcers found at operation. The physicians cooperated freely, and had no hesitation in recommending patients for operation. Fisher at Nakom Paton had only a few such patients submitted to operation, as they did not do so well, and at the end of the period of incarceration had some seventy patients with peptic ulcers in hospital. It may be that the patients at Nakom Paton gathered in after the exhausting trials of the railway working camps were less suitable subjects for surgery.

In the various hospitals established along the Burma-Thailand railway surgical work was carried out as indications and facilities permitted. In most of these the surgical equipment comprised only such instruments as were personal belongings of medical officers or could be taken surreptitiously. It was usual for the Japanese to inform the medical staff, before a move, that a fully equipped hospital awaited them: medical officers soon ceased to have any faith in these false promises. At Tavoy in 1942, Coates was able to carry out quite a variety of surgical procedures, including appendicectomy, repair of ruptured ulcers, strangulated hernia and tracheotomy. Considerable extemporisation was necessary. Operations were performed unofficially in a hut, since the Japanese wished them done in a civil hospital but insisted in sending the patients straight back to the camp. Sterilisation of material was done in an autoclave made out of a petrol drum. At the 55-kilo camp Coates found conditions were so bad that only emergent cases were dealt with, and for these the instruments consisted of a few artery forceps, a scalpel, table knives for amputations, bent forks for retractors, a tenon saw and a soldering iron for a cautery. Catgut was manufactured here from ox intestine. The submucous coat proved too fragile for the purpose, so the peritoneum alone was used after peeling off the other layers. After drying, it was sterilised by being boiled twice in a saturated solution of salt and placed in alcohol. The same method was used later at Nakom Paton, modified by suspending the gut in a tin placed in boiling salt water for an hour. A final addition to this technique was made, defatting the gut in ether and keeping it for use in alcohol and iodine. No infection or other significant complication was caused by this catgut, which resisted absorption in wound for ten days.

It may seem curious, but operations for hernia were frequently performed at Nakom Paton. This was by direction of the Japanese, and as conditions were by comparison reasonable there and rigid care was ensured, the results were good. Slight sepsis occurred in 2 per cent. A standard procedure was followed, the hands were washed in soap and water, and then in alcohol, no more handling being used than necessary. Removal of the hernial sac with transfixion and ligature was sufficient for

some hernias; for others, especially in older men, a Willys-Andrews technique was followed, with the making of a medial barrier to the internal oblique, and transplanting the cord.

In Nakom Paton, too, occasional gall-bladder surgery was done, and a few liver abscesses due to amoebic hepatitis were drained. In a few instances a kidney was removed, and splenectomy for rupture of a malarial spleen performed, and even cranial decompression on a few occasions. Routine operations on the chest such as drainage of empyema offered little difficulty in base areas, where even thoracoplasty was performed on occasion, but emergency procedures were sometimes necessary under very bad conditions. Special surgery of the ear, nose and throat was mostly confined to acute conditions, but in Changi, Major Farmer carried out most routine work. *Otitis media* was rare, but sinusitis was not uncommon, the chronic form being often associated with polyposis. Occasionally here bronchoscopy was done. Tonsillitis was common in Changi, and quite a number of men were sent by physicians to have septic tonsils removed.

The conditions under which surgeons worked varied greatly. On Singapore Island there were passably equipped buildings, and at Nakom Paton a concrete-floored wooden room with wired windows and skylight gave reasonable comfort in operating. But in hospitals serving working camps, which kept moving on, there were few facilities and little encouragement to risk any but emergency procedures. With curious inconsistency, at the 55-kilo camp, the Japanese would not allow the prisoners to build a theatre, but provided an elaborate mortuary. In some camps operating had to be done in small bamboo annexes of poorly equipped wards. Operating tables were usually made of wood or bamboo by the medical staff themselves. Gowns and towels even in base areas gradually disappeared, but in Nakom Paton the Japanese supplied gowns, and caps and masks were also worn. Special instruments were made for surgical use, such as rib shears, retractors, silver haemostatic clips (using a dinner fork), and diagnostic instruments, as mentioned elsewhere, such as sigmoidoscopes, proctoscopes, and ophthalmoscopes.

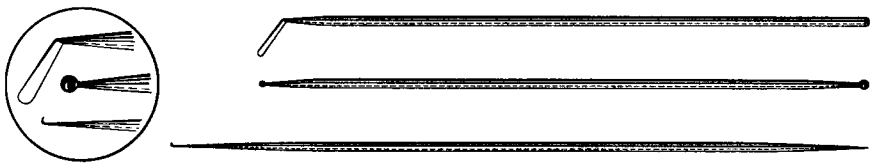
The skin of both patient and surgeon were cleansed by washing and applying alcohol. Alcohol for surgical purposes was distilled chiefly from rice or rice refuse. In Nakom Paton the alcohol factory produced three pints of 90 per cent spirit a day. Distilled water was also made in a number of hospitals. Some of the stills were curious contrivances like those described previously for distilling water.

Drugs were produced from various sources. Emetine has already been mentioned. Alkalies were obtained from wood ash and clay, stramonium for asthmatics was grown at Changi, also castor oil seeds, and charcoal was used for diarrhoeal disturbances when nothing else was available.

Physiotherapeutic apparatus was made by recovered patients which enabled corrective exercise and movement to be used, especially on men who had contractures following tropical ulcers.

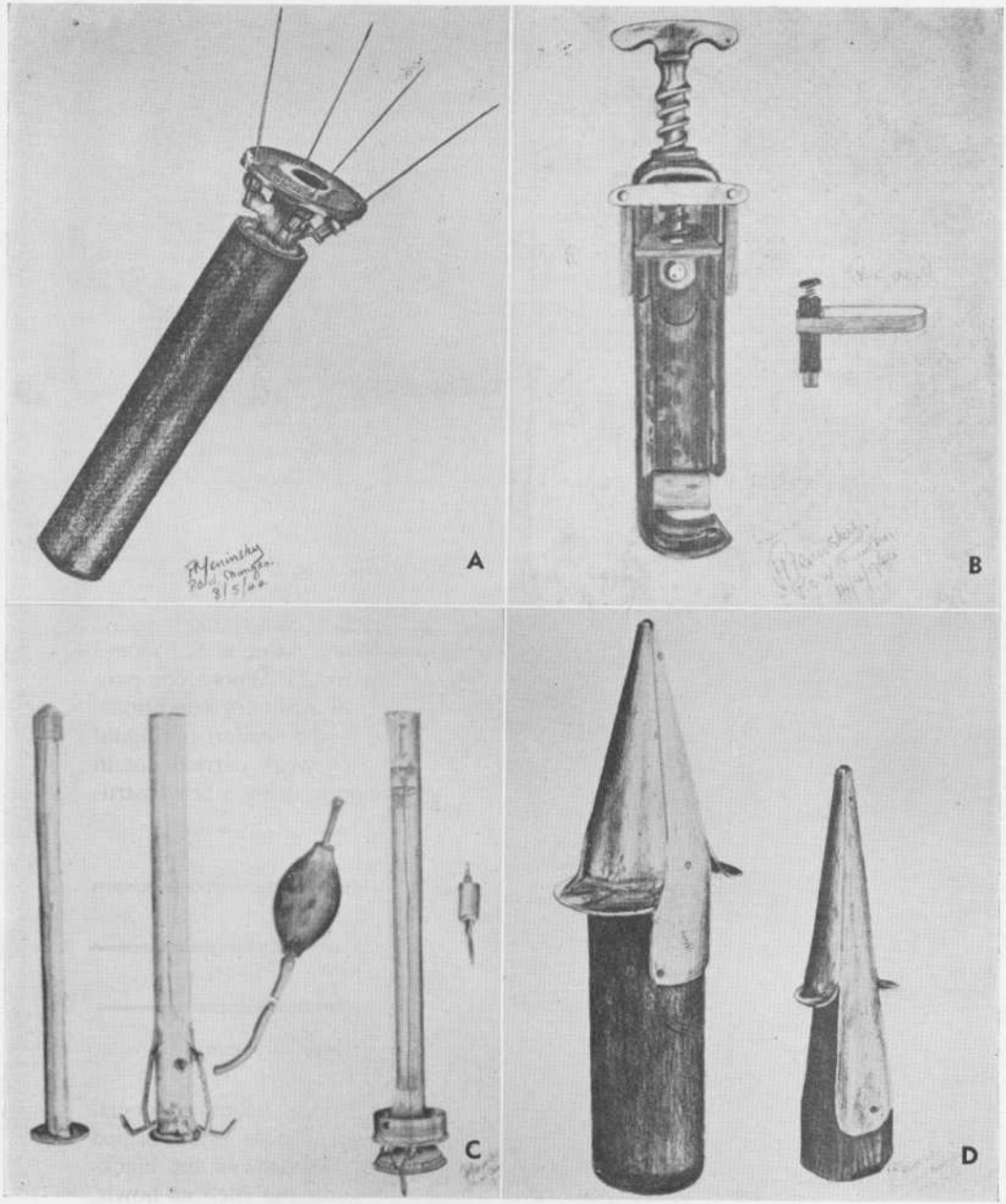
Pathological work was carried out by a number of medical officers, including Majors K. B. Burnside, A. H. Marsden, R. B. Maynard and others. Vaccines were prepared under difficult conditions at Changi, and all routines carried out in fixed camps so far as supplies would permit. At Changi, all ordinary haematological work could be done except haematocrit estimations. Autopsies were regularly performed, a most valuable source of information. Blood examinations were carried out, and a certain amount of biochemical work. The diagnostic value of the bacteriological work was very considerable. Even histological sections were reported on. Stains and indicators were made from different sources by Dr Kostermans, a Dutch botanist in Thailand. X-ray examination was possible in Changi, and though films could not be obtained after a time screening was regularly carried out. It was often of the greatest value as in the estimation of the size of the heart and conditions of the lung fields.

Dental work was continued on Singapore Island as long as supplies lasted. Fillings and dressings were done in large numbers, and dentures repaired and even made. Economy of material and ingenuity in using raw rubber latex, with the assistance of a rubber chemist, made denture work possible: even adaptation of dentures from men who had died was practised. Less caries was found than was expected; this was thought to be due to small food residues in the mouth. Major J. O. Rosson, senior dental officer, claimed with justice that the work done would almost compare favourably with that in a camp of similar size under ordinary conditions. Further details of its remarkable scope are given in the section on dental surgery. Mention should also be made of emergency work carried out in camps in Japan by Surgeon-Commander S. L. Stening, using a few instruments fashioned of fencing wire.



Extemporised dental instruments used in captivity in Japan

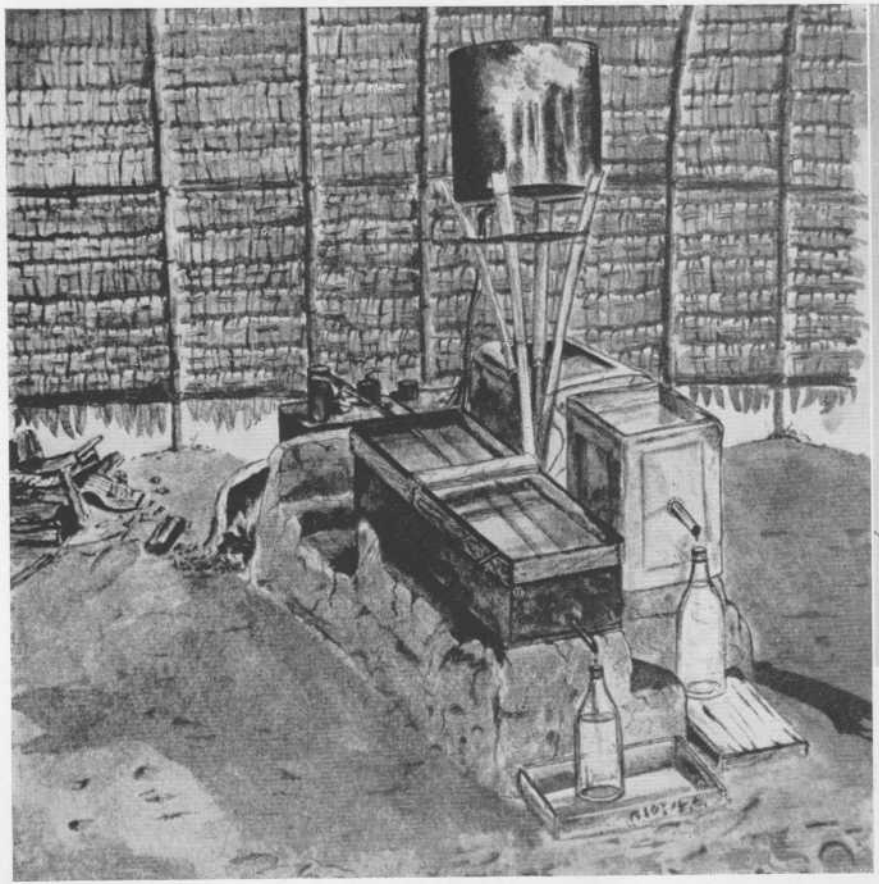
Many ingenious improvisations were contrived by the Allied prisoners, quite apart from the members of the medical corps. These often helped medical work considerably; beds, cleaning utensils, products of the blacksmith's art, leather and fabric bags, appliances for nursing such as bowls, bed pans, feeding cups, washing basins, sterilisers, irrigation feeding cups, and infusion sets, back and leg rests, and suspension apparatus, were all contrived from available material, use often being made to great advantage of the ubiquitous bamboo. Solder was precious, and salvaged where possible, flux was obtained (surreptitiously) from car batteries, or even from human gastric juices. Ingenuity also produced artificial eyes from mah-jongg sets.

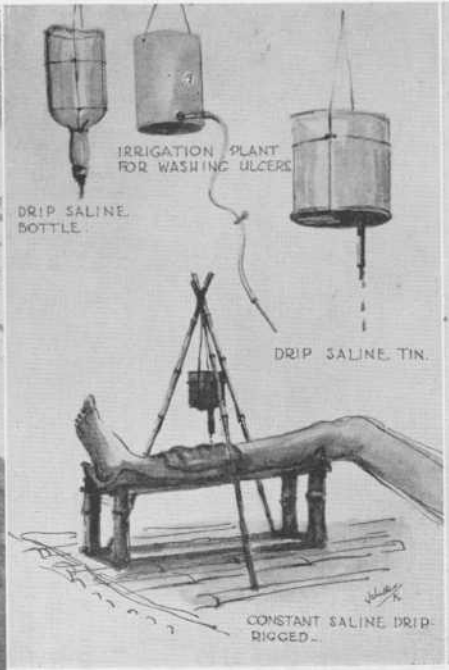


(Drawn by P. Meninsky)

Improvisations, Thailand.

(a) Pinch graft needles. (b) Rib shear and side screw. (c) Sigmoidoscope.
(d) Proctoscope made from aluminium mess tins with wooden obturator.







(Drawn by P. Meninsky)

Improvisations, Thailand.

Improvised still, Tamuang.

Irrigation plant for tropical ulcer.

Artificial leg bamboo pylon.

Ready help was always accorded the medical services by other sections of the forces, and not a little self sacrifice was involved in this. Members of working parties who found packages of drugs on the wharves at Singapore, did not forget to acquire such supplies as came to their ready hands, and so gave Changi hospital some valuable stores.

Blood transfusion has already been described; the defibrination method of Markowitz and Reed is worth another mention for its resourcefulness and the success attending its use.

Wardmastering.—One of the most striking lay services in the cause of medicine was that of "wardmastering". It was common for volunteer help to be employed in caring for the sick, often at the cost of the time and energy of an already tired worker. In "F" Force at Shimo Sonkurai a definite scheme was devised, and here and further on in Burma a system was fully worked out. Major M. D. Price, Royal Signals Corps, and Captain G. W. Gwynne, 2/4th Machine Gun Battalion, A.I.F., have given accounts of this system. The medical officers were far too busy to supervise all ward routines, and wardmasters took the place of authority in their absence. It cannot be pretended that morale was always high among the sick and wretched. The struggle for existence was so grim and discomforts so acute that communal sense at times disappeared, and such antisocial acts as thieving and offences against sanitation were common. Where circumstances warranted it most emphasis was laid on discipline and a high standard of conduct. Supervision of patients and of their nursing was, however, the chief function of these wardmasters, who were selected volunteer combatant officers. They were in close touch with the medical officers and carried out his instructions. The supply of hot water in appropriate containers, the keeping of patients as clean and comfortable as possible, collection and serving of food, obtaining fuel, keeping records and running a canteen were their province. The orderlies were responsible to them, and they enlisted as soon as possible convalescent men in the work of caring for others. As many as 180 patients might be in one ward, and help was badly needed. Captain Gwynne describes the conditions at Shimo Sonkurai during the monsoon. Almost constant rain fell on the bamboo huts, which were mostly unroofed. The troops made some roofs themselves, but attap roofs, used in some camps, such as Tanbaya, quickly rotted; tents and tent flys also soon perished in this climate. On each side of a passage way six feet wide were 30 beds, on which sick men lay, either on bamboo poles or split bamboo. Access was made more difficult by roots and stumps which obstructed the passage ways.

Major Price too found at Tanbaya the need for firmness in organisation in order to have essential work done. In his ward of 180 men, 80 gallons of water a day were carried, and there was an acute shortage of food containers. Construction work was very difficult to carry out: tools were so scarce that on an average a ward would have the use of a saw or axe for only three hours a week in the evening. Records of patients here, as in many other camps, were kept on four inch strips of bamboo.

It took weeks to educate the men to cooperate with the regular carrying out of the necessary duties, such as maintenance of fires and issuing water and food. Not only was it necessary to supervise meals, but to force some patients to eat: without this measure some would have died. The medical non-commissioned officer carried out treatment: the wardmaster ensured that it was done. Trained orderlies, particularly of the R.A.M.C., were often found to have good technical knowledge, but did not always have the power to administer, or the will to carry out menial duties. A.A.M.C. orderlies were often mediocre of attainment, but there were outstanding exceptions. This in no sense belittles the value of the work they did, though the volunteer orderlies often surpassed those of the medical units, and did the worst jobs cheerfully. No doubt the wardmasters sometimes incurred unpopularity, but their contribution was of highest value. Special mention should be made of the work done by volunteers in the outbreaks of cholera. Running a great risk and carrying out the lowliest of physical tasks, they deserve high praise. In all the jungle camp hospitals arrangements could not have been carried out except by voluntary labour. Not only the men trained in nursing work before or after the period of captivity, but the patients themselves, helping to care for those sick who were in worse state than themselves, cooperated splendidly with the medical officers. Of great importance too were the schemes by which all ranks contributed money, food and personal belongings in the interests of the sick. Those who negotiated with local inhabitants for supplies often ran great danger. In various remote places the medical workers rendered inspiring service. An outstanding example of this was seen in the march of a party of 100 Australian and 700 British troops from Nakom Naiyek to Pitsanloke in July and August 1945. Captain Brereton, A.A.M.C., and Captain Poh, S.S.V.F., with eight medical orderlies, cared for these emaciated men, half of whom had chronic malaria and amoebic dysentery, and although the less sick had to carry those unable to walk, only three deaths occurred during this deplorable march.

Mental affections were very infrequent in these prison camps. Among the Anglo-Saxons neurotic disorders were uncommon. A few hysterical palsies appeared towards the end, chiefly among soldiers of the Netherlands East Indies, no doubt illustrating the "infectious" nature of such maladies. Dunlop records personal knowledge of only six suicides. On the whole, despite occasional inevitable bickerings and meannesses, the spirit of the men was one of cheer and mutual help, notwithstanding the glimpses among the sick of the darker places of the heart. Great credit is due to those who maintained discipline, encouraged such diversions as were possible, and set a high example of bearing and conduct. This corporate strength of spirit must have helped greatly to prevent mental disorders. Another potent influence was the almost entire absorption of physical and mental energy in the mere act of survival: no time was left for self-questioning nor any frustration save that exerted by the pressure of a relentless enemy.

Even under the most depressing circumstances an effort was made to keep clinical records of patients in medical units. Where the scanty supply of paper failed the bamboo provided a substitute, and many of these brief clinical records have since been transcribed in Australia as part of the medical history of the men concerned.

Administration too deserves notice, as without this much less would have been accomplished. Perhaps it reached its highest levels in the medical sense when dealing with preventive measures against disease; neither oppression nor hardship blunted that self-discipline which energises work for others.

Educational work among medical officers was not neglected. In all more or less settled centres, where circumstances permitted it, clinical meetings were held from time to time, and some medical societies were formed. All literature which it was found possible to carry accompanied the forces into prison camps, and with opportunities for referring to authorities and consultation and discussion amongst themselves a great amount of medical knowledge was thus disseminated. Numbers of excellent technical reports and articles were compiled, others have been published since; they bear witness to the spirit of these men.

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CHAPTER 54

DENTAL SURGERY IN THE ARMY

ONLY the scope of dental surgical work can be dealt with here; administrative details belong to another section of the story. The dental services which did not even exist in the army at the beginning of the 1914-1918 war, passed through some important phases between 1939 and 1945. The limited number of dentists enlisted in the early stages of the war was inadequate to deal with the great volume of work necessary to make the forces even approximately dentally fit. This was supplemented for a time in one area by a part-time voluntary service. Equipment and supplies were insufficient for a time and even when the 16th Brigade A.I.F. went overseas its dental surgeons had to work with supplies precariously obtained locally. After a long struggle the dental service of the army, previously a branch of medical services, attained separate status, and on 23rd April 1943 became the Australian Army Dental Corps. Dental fitness was an ideal which was never completely realised in any of the armed forces. The task of giving recruits healthy mouths, conserving or repairing the existing dental architecture or providing dentures where necessary, and of maintaining dental health, was a task so great that it was virtually impossible to catch up with it.

Experience in the A.I.F. forced the adoption of a standard for reinforcement drafts which required removal of all badly carious teeth, restoration of those which could be so treated, and making good gaps in dental architecture where necessary. A recruit was considered to need a sufficient number of natural teeth or to possess adequate dentures, not more than four carious teeth to need extraction, and to have a clean mouth with firm gums.

In the Middle East, a surprise was experienced in the low incidence in Vincent's infection. It had been almost epidemic in parts of England, but although cases were not infrequent in Palestine and Egypt at times there was never an outbreak. The treatment was entirely given over to the dental officers, medical officers acting in a consultant capacity about matters of general health. This was a very satisfactory arrangement as adequate local treatment was so important. In Tobruk the besieged force was also relatively free from Vincent's infection, and the same held good in the Pacific Islands. It is interesting to compare the post-war experiences with the British Commonwealth Occupation Force, in which this infection was prevalent. It may be that the higher detergent qualities of the food supplied, and its better balance, helped to lower the incidence from its high level in 1914-1918, but there is no evidence that it is a deficiency state.

Another interesting war experience was that dental caries was much less extensive than might have been expected among prisoners of war. Even after liberation of the 8th Division at the 2/14th A.G.H. dental

officers found that the gums and teeth were in fair condition. Ulcerative gingivitis was rare. The same findings were recorded by dental officers at Changi where a high standard of dental care was maintained despite the ever decreasing supply of materials. Even the few supplies obtained from the Japanese, such as "Novocain", were of poor standard. Medical officers with working parties, as well as dental officers in the large camp hospitals, noted that more damage was done by foreign bodies like pebbles in rice and other soft food than caries. The same was observed by Lieut-Commander S. L. Stening in Japan. He had to devise emergency methods of conservative dental work, there being no dental officer, and had a small set of dental instruments made by a British officer. These were made of fencing wire and tempered in the galley fire and did good work till the end of the period of captivity. In some Japanese prison camps Australian dental officers were required to work regularly in Japanese dental clinics.

Another subject related to dental hygiene was the relationship of fluorine in drinking water to the state of the teeth. In the Middle East "mottling" of the enamel of the kind attributed to fluorine was observed in Arabs in certain areas, but observations were insufficient to relate this to the fluorine content of well water. The subject was included in a research carried out by a dental officer, Captain C. S. Denston, at the instance of the director, Brigadier J. E. Down.

This was a study into the incidence of caries, and the production of dental hypoplasia. Study of natives showed that the peak of caries was between 30 to 49 years: it showed relation to the diet, and varied with the amount of natural food eaten. The civilisation and diet of the white races bring deterioration. Some work was also done on the inhibiting effect of fluorine on caries. Recent literature on the subject shows that a good deal of loose thinking has been involved in the description of enamel as "mottled", as there are a number of causes at work in this change. Fluorosis cannot be assumed from this appearance only. R. L. Reid and N. D. Martin, studying the distribution of fluorine in potable waters of New South Wales and Tasmania, discussed this question of mottling, fluorine content of water and caries. It would appear that most domestic water has a low content of fluorine. Martin has since pointed out that there is epidemiological evidence of a relationship between caries and fluorine, that the threshold value of fluorine necessary to cause dental fluorosis is 1 part in 1,000,000. He found no essential relationship with mottling, but that there was an undoubted beneficial effect from fluorine. One part in a million will not cause positive fluorine balance with fluorosis. There is undoubtedly room for further research in the subject of caries, so vital in Australia.

The dental corps throughout the war really carried out a fight against caries, and spent most of their time in repairing its ravages. It took many months to catch up to this work at the beginning and the great expansion of the three fighting Services added to the labour.

In the army it was not until September 1942 that the number of fillings inserted began to surpass the number of teeth extracted. In that month

the number of each was 600,000, but at the end of 1945, the number of fillings was almost double the extractions. The totals then reached the figures of 1,550,000 extractions and 2,850,000 fillings. About 500,000 dentures were made during the war years by the members of the Australian Army Dental Corps. They found also that deterioration of teeth on the average required that every enlisted man or woman would need one filling every six months and one extraction per year. Experience in Great Britain, described by R. K. P. Miller, showed that out of 24 sound teeth possessed by the young person of 18 years, only 14 remained sound at 30. Some idea of the extent of dental work required by an armed force is gained from the experience of the dental surgeons in Changi gaol hospital. Major J. O. Rosson and his colleagues attended not only the soldiers actually working in that area, but those in working parties as available, and some sent to more distant areas, as for example those in a party of 400 men who went to Java. In 10 months they had attended 4,757 patients, extracted 1,351 teeth, inserted 2,168 fillings, and made 246 full upper dentures and 226 full lowers. They worked till their material gave out, and even made some dentures using raw rubber from latex. During the later period some amalgam was also made from alloys. In the entire period they treated 15,633 Australian, 5,526 British, 3,506 Dutch, 107 U.S.A., and 102 Italian patients. Even when they could no longer do constructive work their laboratories were used for producing surgical alcohol and a local substitute for "Marmite".

In the Australian forces during the war, a radical change was made in the material used for dentures. Acrylic resin was found to have many advantages, and the scarcity of rubber justified the abandonment of vulcanite for acrylic. This was a most satisfactory prosthetic material, though its introduction led many servicemen and women to seek new dentures made from this more attractive material, thus increasing the work done. The introduction of acrylic synthetics expanded the field of activities of dental surgeons considerably.

Early in the war, the important role that they might play in facio-maxillary surgery became evident. Dental surgeons were sent to Great Britain to study this work and soon dental officers were an integral part of the surgical team. In the treatment of fractured maxillae or mandibles they were co-partners with the surgeons, particularly when plastic procedures were performed requiring adequate and trustworthy fixation. This has been briefly described in the section on plastic surgery. Not only did dentists make fixation devices, but they were also called on to make and fit accurate moulds for epithelial inlays, bone grafts and skin grafts. Their natural aptitude for manipulation and mechanical sense fitted them admirably for making appliances of widely different kinds. Thus the dental surgeons' province included a partnership in the handling of wounds of the face and jaw in forward areas, remedial and reconstructive work in base areas and plastic units, and the supply of devices for fractures and injuries of other parts often remote from the mouth. Special attention was given to the manufacture of supports for the sagging face muscles

in facial palsy. On most of these subjects special technical instructions were circulated to dental officers.

Another development of work with acrylic resin resulted in the manufacture of artificial eyes. This was done most successfully by dental officers and mechanics. An impression of the socket was made, and a wax pattern carved from this. A clear acrylic shell was made, inside which the iris was painted in closely matched colours. The sclera was imitated by processing a coloured acrylic inside shell, and the tiny blood vessels counterfeited thereon, usually with fine threads. These products were made in forward bases and were of very high standard.

In working in tropical areas, precautions had to be taken to maintain good condition of equipment. Considerable difficulties were met in transport. In beach landings great care was necessary to obviate spoiling of stores by salt water. The inclusion of dental units among the medical units participating in these landings at a relatively early stage shows how prompt were the measures to secure dental treatment in forward areas. A dental section was even transported over the Kokoda trail by native bearers, and much valuable work was carried out there, including dentures. Dental supplies were also dropped by parachute to forward field units in New Guinea. These were important advances in the work of the Australian Army Dental Corps.

Mobile clinics in dental vans had a limited usefulness only. They could not be brought up to some areas, and only with difficulty to others. Even well equipped fixed clinics, though admirable in settled areas, were not always practicable, owing to the time and transport wasted in bringing men to the clinics. Small sections were often more economical.

Educative work was not neglected by the Dental Corps. Posters, strip films and lectures reinforced advice about the maintenance of dental fitness. Demonstrations were also given to officers of all services in base areas, showing what cooperation between the general surgeon and dental surgeon could accomplish.

The health of dentists sometimes suffered through the long hours they worked, the concentration necessary and the close propinquity with the oral cavities of men who might be in the incubation period of an infectious disease. On some occasions, as after the conclusion of the campaign in Syria, there were considerable depredations of illness among dental officers. Dermatitis of contact variety, especially that due to sensitivity to "Novocain" was occasionally a worry, as an officer once sensitised was severely handicapped.

Dentistry in wartime demonstrates how poor is the average state of dental health in the civil community. This should improve if the prenatal and postnatal dietetic and general care of children is maintained at its increasingly high level. But the problem is a serious one, and deserves the close attention of all interested in public health.

DENTAL SURGERY IN THE ROYAL AUSTRALIAN NAVY

Dental attention began to receive its due in the Royal Australian Navy only in the last two years of the 1914-1918 war, when a dental officer was appointed to H.M.A.S. *Australia.* Previously it fell to the lot of the medical officer to extract teeth or to provide some palliative treatment. During the inter-war period expansion took place; there were 9 permanent R.A.N. dental officers at the outbreak of war in 1939, and facilities had been extended to include prosthetic work. Approval had not been given for the formation of a reserve branch, and difficulty was therefore found in finding enough dentists, mechanics and attendants. These demands grew during the war to an extent unsuspected at first. The rush of naval reservists and recruits increased the numbers of the dentally unfit, and wartime experience showed how much deterioration takes place during long service at sea, especially in the tropics. It has been found that one dentist to 900 men is required. Shortage of dental supplies caused trouble also, as certain items were not made in Australia.

Each of the five cruisers carried a dental officer but the dental needs of smaller ships and of the armed merchant cruisers were not at first adequately met. On H.M.A.S. *Manoora,* for example, the lack of a dental officer was acutely felt. In 1940, only one-third of the ship's company were dentally fit, and until dental officers were carried in these ships the medical officer had perforce to perform extractions and to provide a certain amount of temporary treatment. At times when carrying troops there were up to 2,000 men on this ship and others of similar type. In 1944, dental officers were carried in each of the three landing ships, *Manoora, Kanimbla* and *Westralia.*

With personnel scattered over some 580 ships and establishments thousands of miles apart the problem of making and keeping the men dentally fit was difficult. Ships in the tropics particularly complained of the lack of dentists. Some provision was made in most ports for attention chiefly of an emergent kind, when no facilities were available afloat or in shore establishments. At the base establishments adequate dental staffs were provided: in New Guinea in the later years of the war three dental officers were needed on shore.

Dental facilities were also provided later from the landing ships, but in addition a dental officer with mobile equipment was appointed to the destroyer flotilla, moving from ship to ship as required. This was the most successful method of supplying the dental needs of small ships far from shore bases. A mobile outfit was also found very convenient for the use of a dental officer in New Guinea. Powered units were found the most satisfactory, and in later years were adopted, though they were not freely interchangeable between ships and shore units because of differences in voltage.

Prosthetic facilities were available at all shore depots in Australia, and in the large cruisers, in one landing ship and H.M.A.S. *Platypus,* which



(A. O. Watson)

Dental treatment at Myola, New Guinea.



(J. Belisario)

Dental treatment, Suda Bay, Crete.



(Official U.S. Army)

Dental Section, 2/8th Australian Dental Unit, North Borneo.



Mobile Bacteriological Laboratory, three-ton lorry with trailer attached.

supplied dental service at Morotai. The large depots established well planned clinics; W.R.A.N. dental attendants provided a high degree of service to the professional staffs. Both male and female dental attendants were specially trained; the former were used chiefly at sea and in tropical shore stations. Dental mechanics were eventually very scarce in all the services. The army dental service set up its own training centre and satisfactory mechanics were obtained for other services from this source. At the end of the war 22 dental mechanics carried out the prosthetic requirements of 39,000 members of the R.A.N. The need for a reserve of dental officers was clearly established during the war.

DENTAL SURGERY IN THE ROYAL AUSTRALIAN AIR FORCE

The Royal Australian Air Force Dental Service was posed with a difficulty of considerable magnitude in its work, that of the movement and scattering of units to a degree which was not experienced by the army. For example, in 1943, 45 per cent of the R.A.A.F. units had a strength of less than 250 and 27 per cent were between 250 and 500. On the mainland of Australia, however, most of the units were mainly at fixed stations. Further, the proportion of technicians in the air force gave rise to considerable movement from unit to unit. Units in forward areas rarely came out of the line to rest, and their treatment had to be given in their forward location. Training in the R.A.A.F. required a complex organisation involving technical trades, and training in aircrew duties and other specialised procedures, and here too dental attention had to be fitted into the training pattern and programme. The aim of the dental service was to make men dentally fit in base areas and to keep them fit in forward areas.

In the important and extensive work in base areas large centres were established, such as those at the Melbourne Showgrounds and at transit and embarkation depots. At initial training centres of various types large teams of dental officers and mechanics and other personnel were made available, with the object of making the men dentally fit by the time they were ready to be posted to operational units. At embarkation depots it was necessary to deal with men going overseas, or to New Guinea, so that the required dental work could be completed before their embarkation. This principle of achieving dental fitness during the vital preparatory periods, so important in an air force, was fulfilled as far as possible. Mobile dental sections were used with advantage in New Guinea, in Australia and in England to extend the range of dental services.

On the administrative side the organisation followed that of the Royal Air Force. The D.G.M.S. controlled the dental branch of the medical services, and the senior dental officer, though retaining complete professional freedom as Director of Dental Services, was always a Staff Officer of the D.G.M.S. This system worked very successfully. It maintained unity and contact with the medical services, while enabling the Director of Dental

Services to direct the professional and dental administrative aspects of the dental service. Subsequent experience with the British Commonwealth Occupation Force in Japan has confirmed the practical value of this organisation.

On the technical side the aim of the service was to foster conservative dentistry as far as possible. This ideal was kept in view even in the difficult period of 1940-1941, when all dental services were labouring to catch up with the huge volume of work. With aircrew trainees, for example, the great numbers of fillings by far surpassed the small numbers of extractions. The extraction rate never approached the filling rate as it did in the army. Care was taken to maintain a high standard of dental attention for all aircrew members.

The use of acrylic resin for dentures was introduced into R.A.A.F. practice before other services and proved very satisfactory. Dental officers cooperated with surgeons in plastic manoeuvres in base areas, and made technical contributions of value in a number of special conditions. For example, ear plugs were made by the mechanical section for test bench workers, and a special fitting was contrived by the dental section for the control and prevention of *aerotitis media*. This was an individual appliance designed to bring the jaw forward and thus permit the release of the orifice of the eustachian tube.

The contribution of the dental service towards raising the general standard of dental fitness was one of substantial importance.

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CHAPTER 55

DERMATOLOGY

"The skin is slow to forgive" (J. T. Ingram)[1]

CIVILISATION has but poorly conditioned the reaction of the human skin to unusual strains such as are met in war waged in tropical countries. It is interesting that embryologically the epidermis has the same cellular ancestry as the nervous system: both these ectodermal structures are ready to show resentment to an unfavourable environment, and the influence of the mind on the skin cannot be disregarded.

IN THE MIDDLE EAST

When the 6th Division of the A.I.F. went to the Middle East it was fully expected that a considerable proportion of hospital beds would have to be allotted to men with maladies of the skin. Nevertheless no special arrangements were made to cope with this need, and the official *War Office Manual of Disease in Tropical and Sub-tropical Areas* devoted only seven of its valuable 280 pages to skin diseases. It soon was evident that more men were attending sick parades for skin lesions, and more being admitted to hospital than had been anticipated. The conditions seen were chiefly those of civil life, aggravated by conditions of service, climate and locality. No appreciable hazard was added by the existence of other forms of skin disease among the native population.

The lesions most frequently seen in the Middle East were (1) various forms of dermatitis associated with sweating and mechanical or other irritation, (2) pyodermia in forms ranging from indolent ulcers to furuncles, and (3) parasitic infestation. Naturally there was overlapping in these classifications. The first class of affection showed many forms and degrees of reaction of the skin, from erythematous and papular eruptions to ecthyma and weeping eczema. Vesicular rashes of the hands and feet were common, and were prone to relapse. The axillae, groins and other flexures were often affected with lesions associated with disordered skin function, of hyperhidrotic or seborrhoeic type. Weeping cracks behind the ears were often related to seborrhoeic organismal lesions of the scalp as well as those of the larger flexures. Secondary infections often occurred. Frank infection was an evident cause of the various types of pyodermia; most trouble was given by the infected shallow ulcers known as "desert sores" and many other local names. These were the centre of considerable controversy.

It is perhaps best to dispose first of all of the septic "desert sores" and the parasitic diseases of the skin before returning to the first category, a large vague group not clearly connected by established aetiology.

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[1] *British Medical Journal*, 24 July 1948.

Septic sores were encountered in all the theatres of war. During the summer of 1940 while the oversea troops were still training in Palestine, the loss of men from this condition was considerable, and an investigation was carried out by a committee of medical officers appointed by the D.D.M.S., I Australian Corps. A signal was received from army headquarters in Australia pointing out that during the 1914-1918 war septic sores were found to be due to vitamin deficiencies. This was well known to the A.I.F. medical services overseas in 1940, and the possibility had then already been examined. On 11th September the committee reported on the results of their enquiry. Investigations were carried out in the laboratory and the field. Excretion tests were made by Miss M. Freeman to detect any lack of saturation with vitamin *C*, that is, any degree of latent scurvy, in men from three infantry battalions and from the staff and patients of a hospital. Following the administration of 300 milligrammes of ascorbic acid to twenty-nine men a doubling of the urinary output of this vitamin was observed. This indicated adequate tissue saturation. The average concentrations (1.9 mgm per cent) were the same in men who had infected sores and those who had none. Some hospital patients showed an average concentration of 2.4 mgm per cent, which fell to 2.0 mgm after the test dose. This fall was not significant, but indicated a lack of vitamin *C* in the diet of these men. This was to be expected, as they had received no supplementary ration of citrus fruits as was given to the men in the infantry units. In spite of this sores were common in the infantrymen, and infrequent in the hospital patients.

Bacteriological investigation showed that an infective agent was present, usually a haemolytic streptococcus, and often a pyogenic staphylococcus. Different streptococcal strains were sometimes detected in different patients. There was no evidence of diphtheritic infection as a factor of primary importance, though an occasional case of diphtheria of the skin was seen. Fusospirillary organisms were not a feature of the bacteriological picture.

The conclusion drawn from this work was that the incidence of sores was not connected with vitamin deficiency; it was pointed out too that the hospital patients were shielded from trauma and their skins were clean, whereas the infantrymen under training were subject to minor abrasions, and lacked full facilities for personal cleanliness during field exercises. The lack of any army issue of soap was a contributory factor; others were the need for sterilising blankets by airing and sunlight, and the neglect of simple first aid for minor injuries.

A frequent and annoying type of septic lesion was due to sandfly bites. Some people were relatively unaffected by sandflies, others became sensitised to the bites and suffered from the irritation of raised reddish brown papules on the exposed parts, such as the wrists. Scratching soon produced bullae which readily were infected, causing impetiginous sores. The experience in the Middle East indicated that there were multiple aetiological factors in the production of septic sores. There was no doubt as to the important role played by trauma; sores appeared on the sites of

damage, though this might often be very slight. Infection too was of obvious importance. It is, however, not easy to explain why the skin should break down easily and why it should not promptly reject or overcome infective agents. There were possibly other factors besides those of hygiene. Though vitamin *C* was unproven as a significant factor, it cannot be said that this or other nutritional elements may not have been relevant. The role of sweat and of sebaceous secretion and of direct sunlight is also uncertain. Surely sunlight must have been of some importance; septic sores were observed to be commoner in fair people with delicate skins, and they practically vanished in winter.

In addition to indolent infected ulcers, pyodermia of various types helped to keep beds occupied in skin wards. The usual furuncles and subcutaneous suppurations were seen, including pyogenic activation of acne, but more important were the complications of other eczematised lesions.

Treatment varied greatly with individual preference and local facilities. Preventive measures recommended included the adequate cleansing of the skin of the whole body, airing of blankets, and prompt attention even to trivial abrasions. A soap issue was recommended by the committee: this was achieved mainly through the Australian Comforts Fund. At a later date soaps containing antiseptics were found to cause dermatitis (during 1942 twenty out of fifty-eight men were seen in one hospital) and on the advice of Colonel J. C. Belisario, who acted as Consultant Dermatologist to the A.I.F. in the Middle East, the use of medicated soaps was forbidden, and they were withdrawn from the canteens. Swimming was encouraged where units were camped near beaches.

The committee recommended that minor wounds should be treated by shaving the surrounding skin, cleansing by soapy water, and removal of hairs in the infected zone. After application of spirit elastoplast was kept on for four to seven days. Sores in the early stage could be treated by cleaning and the application of 3 per cent white precipitate ointment or eusol. Simple occlusion as described was an effective form of treatment which had many adherents, though all did not agree that elastoplast was universally suitable in hot climates. Others preferred local application of sulphonamides, but this was not successful in all cases. Acriflavine gave some good results, but caused irritation to those who were readily sensitised by it. Other applications used with success were gentian violet 2 per cent, silver nitrate 2 to 5 per cent and mercury perchloride 1 in 5,000. Men in hospital usually did well with non-irritant lotions, such as boric acid. There was in fact no specific.

Throughout the whole period during which A.I.F. units operated in the Middle East septic sores gave trouble. They flared up in greater numbers during campaigns when hygiene and simple care could not always be carried out. In the desert campaigns and in Tobruk many men were troubled by these lesions. In Syria during the latter part of the campaign "Syrian sores", as they were there called, were prevalent. The medical officer of the 2/6th Field Regiment records how he and his orderly

dressed sores all day and also at night. The men used all sorts of material to cover sores on their exposed skin, where the flies constantly worried them, and there the lesions soon became ecthymatised or eczematised. "Tannafax", calomel ointment from prophylactic outfits, and cigarette papers were all used when dressings were scarce, and even the juice of green olives, advised by the Arabs, which was found of no value.

Adequate care would heal these lesions, though healing was by no means always prompt. Their potential seriousness was apparent later on in the 8th Division, where during the Japanese occupation many men lost limbs and lives from severe spreading infections beginning from septic sores. This is described in the section on special conditions occurring in prisoners of war.

Parasitic infections of the skin included various forms of tinea, scabies and pediculosis. The exact incidence of tinea is impossible to estimate, but though common, it was over-rated. The varieties usually seen were on the feet, and in the axillae and groins. The finding and identification of fungi on microscopic examination needs both time and experience, and outside hospitals this could not easily be done. Many of the lesions seen were eczematous when the patient entered hospital, and there was often no evidence that these were or had been tineal in nature.

Much of this difficulty was due to the readiness with which pathological reactions of the skin occurred in response to unfavourable conditions. An even more important complicating factor was over-treatment. "*Tinea cruris*" or "dhobie itch" provided a good example. These names were often used where there was little to suggest a tineal infection, with no raised edge, and no demonstrable fungus; the lesion was frequently an intertrigo, due largely to mechanical causes. The application of strong fungicides to these lesions was too often a sort of medical conditioned reflex which produced most unfortunate results. The affected regions not infrequently showed the effects of chemical irritation with eczematisation, cracking, and often superadded infection. Occasionally the scrotal skin also suffered, with complete immobilisation of the patient. It must be remembered that even the keenest and most competent unit medical officers had little special training in dermatology, especially in military surroundings. Often the patient was self-treated when seen, and venturesome orderlies sometimes let zeal outrun discretion. The same strictures applied to many other lesions of the skin, in which over-treatment was common. Even nurses expressed some surprise at the number of palliative dressings which were applied by cautious dermatologists before they attempted vigorous treatment.

Uncomplicated tinea usually responded well to Castellani's paint or Whitfield's ointment, though ointments were in general unsuitable preparations for treatment when external temperatures were high. The dyes and silver nitrate were also used, and found valuable if caution and correct indications were observed. Eczematous lesions needed preliminary treatment with saline, sodium sulphate solution, isotonic or hypertonic, or diluted Burow's solution.

Meanwhile other oversea units were also experiencing troubles with skin disease. In Colombo the 2/12th A.G.H. found that 13 per cent of patients admitted to the medical division had skin complaints. In Malaya the 8th Division was similarly affected. Here tinea of the feet was prevalent, and during the training period the A.D.M.S. issued special instructions to minimise infections in showers and to prevent maceration of the feet by the use of 1 in 3,000 permanganate of potash and spirit followed by powder. The use of a boric dusting powder with or without a small percentage of salicylic acid was also found useful in Palestine. Experience on all fronts proved how essential was careful periodic inspection of the feet of all men on service.

Scabies was not at first a serious waster of men, but during 1941, 1,057 men needed hospital treatment. Despite all optimism in the treatment of this infestation, it was not always found easy to steer a middle course between a high relapse rate and sulphur dermatitis. Sulphur ointment was the only medicament available in quantity. Scabies and sulphur dermatitis have been found simultaneously in the same patient. The thiosulphate solution method was tried on a small scale, but was less reliable. Beta-naphthol and benzyl benzoate were not obtainable. It is not possible to say how important blanket de-infestation was in preventing relapses. Blankets were not always sent in with patients for sterilisation, but the impression was gained that it was the patient himself who was the source of relapses. Nevertheless there was evidence that under certain conditions blankets might convey infection, as for example in staging camps where thefts of blankets gave rise to the practice of withdrawing blankets every day and reissuing them each night. A relapse of 5 to 10 per cent was not uncommon, but this could be reduced by scrupulous attention to detail. As so much of this had to be left to orderlies of varying grades of experience, even careful supervision did not prevent relapse. A clinical feature of scabies in the Middle East was the frequency of genital lesions, and the relative infrequency of "burrows" on the hands and wrists. Scabies was not of great importance in the Australian forces; during the later years it was not significant among the many other problems in tropical dermatology, but localised outbreaks in unexpected areas showed that it could not be disregarded.

Pediculosis was seen only in moderate numbers, chiefly in the pubic region. Here the simplest method was found to be shaving and thorough spraying of the area with an insect repellent solution. *Pediculosis corporis* was rare except in the campaign in Cyrenaica, but never assumed great importance. *P. capitis* was very rare.

As previously pointed out, even apart from infected sores and parasitic infections, the incidence of other skin disease was considerable. Many hospital beds were occupied by men with non-suppurative forms of dermatitis. The acute symptoms settled down well in hospital as a rule, but the lesions tended to become lichenified in many cases, and then required long treatment. For these the need of X-ray treatment was felt. A number of patients were so treated at the Hadassah Hospital in Jeru-

salem, including some with severe infected acne. Requests were also made for an ultra-violet and an infra-red lamps for treating skin disease.

Towards the end of 1941 the A.D.M.S. of Base Area Middle East suggested the establishment of a skin centre at an A.I.F. hospital, with 150 to 200 beds, with a dermatologist attached, and with perhaps a therapeutic X-ray plant provided. Through changes in the military position this was not done. Meanwhile trained dermatologists were available for work in hospitals as the Australian forces grew in strength in Palestine, and the posting of experts to these units and the influence of an adviser in dermatology helped greatly in raising the standards of diagnosis and treatment. Technically they ranked as physicians, but in most instances commanders were enlightened enough to use them as dermatologists. There was no question that they were needed.

During 1940, 1941 and 1942 the A.I.F. in Middle East had a constant morbidity rate for diseases of the skin and cellular tissues of slightly over 100 per 1,000 per year. The actual figures were 110.25, 105.40 and 103.89.

Before any larger schemes could be put into effect the main body of the A.I.F. returned to Australia, leaving the 9th Division. During 1942 this division continued to show a high incidence of skin disease. It was observed that generalised dermatitis was common; though the causes were in the main obscure, the nature of the skin reactions suggested an allergic cause in some instances. In addition sweating, heat and the irritation of clothing also seemed to play a part. There was no special novelty in these lesions, but time and patience were necessary to restore to the skin the capacity to withstand service conditions. This of course is one of the burdens of the dermatologist and his patient.

During 1942 two interesting outbreaks of irritative skin lesions occurred due apparently to some form of sensitivity. One, in a field regiment, was an outbreak of urticaria, mostly papular in type, occasionally heralded by hay fever. The other occurred in a railway construction company: irritable papules and bullae appeared without apparent reason. Investigation failed to disclose any bites or insects, and the outbreak was thought to be of botanical origin, possibly due to air-borne spicules of some kind.

A certain number of malignant and pre-malignant conditions of the exposed skin were diagnosed in the men in Palestine, caused no doubt by the intensity of solar radiation. Difficulty occurred in connection with the X-ray treatment of these. This was undertaken for the army by the Hadassah Hospital. In the first instance the dosage was ordered by a dermatologist of the A.I.F., but later by the doctor administering the treatment. There was in fact some divergence of opinion about dosage. In some instances destruction of tissues was noted afterwards, and this was, in the opinion of the British adviser in radiology and the Australian dermatologist, due to radio-necrosis. The lower dosage employed in Australia for skin carcinomata is not due to any essential sensitivity in skin of Australians but in the opinion of Australian dermatologists to their own greater experience in lesions of this type.

When the balance of the A.I.F. overseas returned to Australia the field of military dermatology, like that of military operations, had widened greatly, and included the Australian continent and action areas in the South-West Pacific. It will be best now to traverse quickly general dermatological developments in these areas, concentrating on particular problems as they arose.

IN AUSTRALIA

In 1942 the R.A.A.F. found it necessary to issue a comprehensive detailed instruction on the diagnosis and treatment of skin diseases.

In the army in Australia the position also caused concern. In the Northern Territory a special survey was carried out by Lieut-Colonel A. L. Dawson for the D.G.M.S. There were two army general hospitals in the Territory; at one of these 20 per cent of the patients admitted had some form of skin disease, and at times this figure rose as high as 60 per cent. A field ambulance found that skin diseases represented one-third of the conditions treated. The skin conditions encountered consisted of sweat rashes, affecting flexures, septic sores (including furuncles), tinea, various forms of dermatitis and eczema, and other lesions as seen in civil life. Sweat rashes were exceedingly common, but could be controlled by correct measures, such as drying off sweat as it formed, regular washing with non-medicated soap, and use of borated powder. Field ambulance figures showed that septic sores made up nearly half the skin conditions treated. They were of the usual type, with ulcers of from 1 to 3 centimetres in diameter. Colonel Dawson pointed out that these were exactly the same in appearance as those found in many other places, including Palestine in the 1914-1918 war, and Northern Australia over a period of years. He thought the experience of 1917 showed that vitamin *C* had some influence, and commented that there was a shortage of fruit and fresh vegetables in the Territory. Local experience showed that bathing and protection from skin damage and prompt treatment of lesions were important, and that, provided crusting was removed from the sores, any occlusive mild antiseptic was successful. Solar sensitivity was noted in some men as had previously been reported among troops in the Darwin area, where the skin conditions were similar.

"CHROME" DERMATITIS

In Eastern Command attention had been for some time directed to the high incidence of dermatitis of a uniform type. This had previously been noted in Palestine as above mentioned. Preliminary observation at the 113th A.G.H. at Concord and among out-patients indicated that sensitivity to chrome was a factor of possible importance, and the D.D.M.S. Eastern Command authorised a board to make full investigations.[2] This board issued a report early in 1942. The rash in question was described as erythemato-papular or vesicular, with occasional weeping. It affected

[2] Lt.-Col. A. L. Dawson, Sir Norman Paul, dermatologists, and Maj. F. S. Hansman, biochemist and pathologist.

a uniform distribution in front of and behind the axillary folds, on the back (neck, shoulders, lumbosacral region and buttocks), the genito-crural region, the front of the thighs and legs, the collar and cuff lines, elbows and knees. The patients affected had been wearing drill uniforms dyed with chrome salts, and testing with a chrome solution produced local and general reactions. The solution used was 10 per cent sodium chromate, previously used as a test substance in chrome dermatitis occurring in the tanning trade. This was a six-valent salt, such as was used in dyeing, but experiment proved that sweat could reduce this to trivalent salts, which were believed to be responsible for the dermatitis. Patch tests were also used. The site chosen for skin testing was in the neighbourhood of fading lesions. Controls tested with the same solution showed no evidence of sensitivity. Examination of the clothing actually worn showed that the drill was in some instances quite harsh, and its texture was such that loose ends and seams could readily chafe the outer epithelial cells so as to allow access of sensitising quantities of soluble chrome salts. Histories of patients suggested that the time taken to produce susceptibility to chrome varied, in some the period was thought to be some three months, in others over a year.

The board pointed out that chrome dye was not used for military clothing in the United States of America. It was found that most manufacturers of khaki socks in Australia did not use chrome dye. Further experiments were carried out to ascertain the amounts of chrome extractable from dyed fabrics: this varied considerably, but from all samples chrome could be mobilised. The investigating board recommended that information concerning chrome dermatitis should be disseminated among all A.A.M.C. officers in Australia and overseas; that men proved to be suffering from chrome dermatitis be protected by suitable underwear and when available by chrome-free uniforms, and further, that no chrome should be used in dyes or mordants for socks, and that only khaki serge and drill be used for uniforms which conformed to a standard low dermatitis potential. The question of abandoning chrome for vat dyes was later discussed. The board expressed the view that sensitisation to chrome would increase as time went on, thus multiplying the problem many fold.

The whole problem raised considerable controversy, and opinions differed in different areas. On 16th April 1942 a technical instruction was issued on chrome dermatitis, in which directions were given for men with persistent dermatitis to be referred to dermatologists in base areas for further investigation and for treatment. Avoidance of soap on affected parts of the skin, and also of any but neutral sedative applications was advised. Colonel Fairley, Director of Medicine, A.M.F., advised the D.G.M.S. that the number of men with chrome dermatitis was apparently small, even when drawn from such wide areas as various parts of Australia, the Middle East and Malaya. Though attention had been called to forms of dermatitis of apparently allergic type overseas, the numbers there were thought to be small. Lieut-Colonel Dawson, the president of the board, had not seen more than sixty cases from all sources. The decision made

was therefore to collect further data among troops, and institute independent investigations in other areas. Colonel J. C. Belisario carried out work at Armidale, N.S.W., and reported to Colonel A. M. McIntosh, D.D.M.S. of that area, that 10 per cent chrome solution was too strong for skin testing and that the following points were essential in making observations on the subject: (1) A negative result of a patch test to be of value must be on a healed, previously affected area; (2) that a positive result to a test to be of value must be obtained with a piece of suspected worn material moistened with water; and (3) that prompt recurrence of the dermatitis after the wearing of a suspected shirt by a patient still under observation in hospital was strong presumptive evidence of the dye in the shirt being the cause.

Further work was done in the 115th A.G.H. Melbourne, and reports made by Major J. H. Kelly, and by Majors Colin Friend and Ivan Maxwell. Major Kelly considered that in spite of positive results of skin tests with chrome, dermatitis was not truly specific, since four out of twenty civilians with ordinary eczema and no history of exposure to chrome gave positive results to 10 per cent sodium chromate. He observed many signs of autonomic imbalance in the patients with "chrome dermatitis", and noted particularly their hyperhidrosis. He advised that the terms "neurodermatosis" or "eczema" be used instead of "chrome dermatitis" and that the presence of a skin reaction to chrome be noted in the records.

Majors Friend and Maxwell reported that chrome sensitivity was a definite clinical entity, but that its extent in the army needed further investigation. They tested a series of soldiers who were free of symptoms, and who had worn chrome-dyed uniforms over long periods, but found no evidence of sensitivity. They suggested that men sensitive to chrome should be transferred to other duties not requiring the wearing of chrome dyed uniforms. They agreed with the recommendation of the first board in N.S.W. that all cotton fabrics used for khaki material should be treated only with vat dyes. The matter reached ministerial circles also, but the Minister for the Army in October 1942 was able to give an assurance that careful observation had not revealed a large number of cases and that few fresh cases were appearing.

In general it can be said that the occurrence of various manifestations of dermatitis was a problem of importance, but whether it was correct to lay stress on the significance of chrome as a factor was another matter. Dermatologists agreed that varying degrees of skin reaction were seen in patients of a particular kind, who sweated freely, sometimes literally dripping sweat from the axillae and who frequently had clammy moist extremities, tremor, tachycardia and a labile blood pressure. The description fitted some of the manifestations of the so called "effort syndrome". The skin reactions varied from erythema to a papulo-vesicular rash and to a weeping eczema or to lichenification and pigmentation. Multiple sensitisation was noted by the original board and other observers. The history often dated back to the issue of new clothing, particularly summer clothing, in which there were other potential factors besides chrome. There

was some evidence of irritation and sensitivity to some proprietary washing powders used by men in washing clothes in areas where presumed allergic forms of dermatitis were occurring.

Assuming that chrome dermatitis was an entity, which seems beyond question, the important points were its true incidence, and its diagnostic criteria. In this connection the optimum strength of the test solution of chrome was debated, the strength advised by Major Hansman was generally believed to be too high, and the site selected near a previous and not completely cleared lesion was criticised. The multiple factors known to be concerned in allergy and its external manifestations made it questionable to rely on a test of this nature.

Finally, the issue of chrome-free clothing by no means ended the troubles of some of the patients, which is quite consistent with an allergic state. On 15th May 1943 the original technical instruction was cancelled, and another substituted which repeated the descriptive and therapeutic details but directed that the name "dermatitis (? allergic)" should be used. Copies of the reports had been sent overseas, and early in 1943 these were accompanied by a letter from Brigadier Fairley, Director of Medicine, A.M.F., in which he stated that at that date the estimated number of cases of "chrome dermatitis" did not exceed 250, that it was not practicable at that time to change from chrome to vat dyeing, that at Australian headquarters it was felt that too much importance had been attached to it from the military point of view, and that the problem was not so big as at first thought. Numbers of cases of dermatitis of allergic type were reported from Northern Territory, Western Australia and New South Wales, but the diagnostic criteria for chrome as the important cause varied with the views of dermatologists. It must be realised, too, that the aggregation of allergic patients in base hospitals tended to give there a somewhat distorted view of the military problem. As time went on the original prediction that allergic dermatitis must continually increase if chrome dyeing was not abolished, was not fulfilled.

In 1942 when the 114th A.G.H. at Goulburn held many men with chronic or relapsing skin lesions, Captain Goldschlag remarked that dermatitis of contact type had clinical features of the allergic variety, and was very resistant to treatment even if the affected area was not in contact with the allergen. He found that men with the affection alleged to be due to chrome usually did not react to khaki material on test, and did not show "flares" on the wearing of khaki uniform on hot days, though Major Hansman in his original series had described recurrences on the wearing of khaki drill. In some hot areas, too, as in Northern Queensland, men sent to the base for investigation relapsed repeatedly if returned to their units. They were best dealt with as individuals and not under a general instruction, but inveterate relapses made profitable military service most unlikely. In Western Australia relapses were almost invariable, and discharge was the only solution. It does not follow that exposure to chrome was the only cause in such relapses. The question of camouflage dyes causing sensitivity had been raised earlier, when chrome attracted so

much attention, and was brought up in several areas at later dates. However, this seemed most unlikely, as it did not exist among workers making the dyes, and tests on volunteers failed to produce symptoms.

The Australian Director of General Stores and Clothing reported that practically all strap leather was free of chrome and that drill was dyed by salts leaving a chrome residue of from 0.8 to 2 per cent. Vat-dyed shorts and trousers were being provided for patients allergic to chrome. The Director of Ordnance reported that the capacity for vat-dyeing was limited, and this could not be used for all khaki drill.

In the Royal Australian Navy vat-dyed khaki was chiefly used, with some chrome-dyed garments from army sources. The latter were mainly woollen, which the ratings disliked, but even so no trouble was experienced. In the R.A.A.F. the Consultant in Dermatology, Wing Commander J. Witton Flynn, found only a negligible incidence of dermatitis due to chrome idiosyncracy.

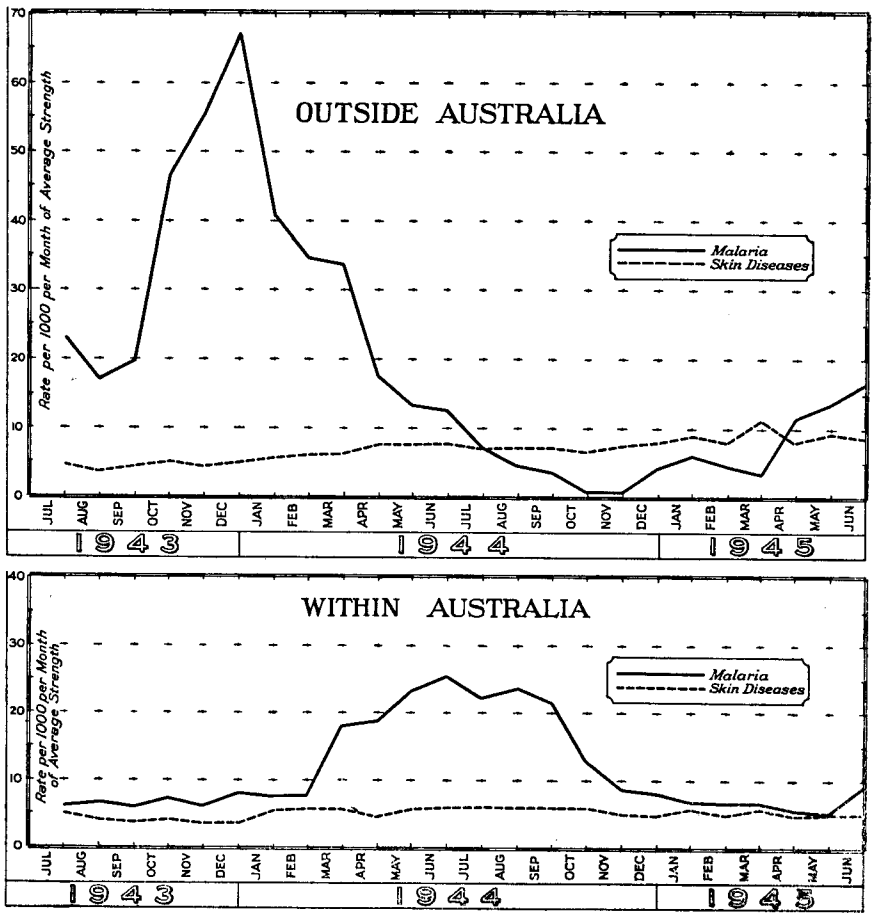
By the beginning of 1944, experience had shown that the considered policy of the medical services on this controversial subject was justified. Comparison of methods of investigation in different areas showed that these differed considerably in strengths of test solutions used, in precautions and controls, and in interpretation of results. Enquiries from the War Office brought the reply that the total number of cases had not been great, and that no change in dyeing had been made. Though dermatological diseases continued to cause a waste of manpower throughout the years of war, less was heard of chrome as time went on. It was desirable too that the faith of soldiers in such an essential as clothing should not be lightly shaken, except for serious and well-established causes that could be a menace to health. However, the work was valuable, and shed light from more than one angle on military dermatology. It emphasised what was known, that chrome was a potential irritant, and the ultimate abandonment of chrome dyeing for uniforms could be seen as a desirable step when this became feasible.

FACTORS IN SKIN DISORDERS IN TROPICAL AREAS

Now we may consider the skin conditions which caused most trouble during 1943-1945, particularly in the tropical parts of Australia and the island combat areas to the north of the mainland. The serious military risk of malaria inevitably occupied the stage of preventive medicine until the final stages of the war, but it became more evident as time went on that skin disease was a stealthy stealer of manpower. Indeed for a time the casualties from skin diseases exceeded those from malaria.

During the twelve months from April 1943 to March 1944 the average monthly hospital admissions for skin diseases per thousand strength for the A.M.F. were 3.64; the total admissions for all diseases for this period were 100 per 1,000. The corresponding figures for Northern Territory alone were 4.98, and for New Guinea alone 4.47. Comparative figures for 1943-1945 for malaria and skin disease are shown in the accompanying graph. The brief account already given of the conditions seen in

Northern Territory indicates the nature of the problem there. In New Guinea and other islands where Australian troops were stationed the problems were comparable in scope, but there were some differences in their nature. The scope of these troubles in New Guinea may perhaps be more clearly realised from the following examples. In aid posts the numbers of those treated for skin troubles from one infantry battalion rose to a level of 250 to 350 in a month. Of these 10 per cent went to hospital. Again, as many as 30 per cent of men admitted to hospital in a forward base were sent to Moresby for X-ray treatment or to the mainland for prolonged treatment. In the Madang area in 1944 half of some battalions were being treated for skin troubles for a time, till a preventive campaign waged through orders and education reduced the numbers. The commonest conditions seen were sweat rashes, either combined with intertrigo in the



Relative incidence of clinical malaria and skin diseases 1943-1945

flexures, or on the hands and feet; *miliaria rubra* (prickly heat), follicular infections, *Acne vulgaris* and tinea.

More dermatologists were now available as specialists, and were used for control and implementation of treatment, instruction of medical officers and the initiation of preventive measures. The practical method of using dermatologists as consultants in their own areas proved most helpful. The introduction of superficial X-ray therapy in New Guinea due to the insistence of Colonel Belisario, commanding the 2/5th A.G.H., proved a substantial aid to treatment, and shortened the stay of men in hospital. The machine was ostensibly obtained for the treatment of gas gangrene, on the recommendation of Colonel W. A. Hailes, Consulting Surgeon; only two patients with gas gangrene were treated, though with immediate success, but the value of this measure in the growing numbers of skin lesions was soon established.

The factors concerned in the high incidence of skin disease in New Guinea and similar areas were the climate, the existence of some skin infections there, the protective clothing made necessary by anti-malarial measures, and contact with chemical irritants of various kinds, and eruptions due to drugs. These diseases may be divided into the skin rashes or lesions chiefly due to environmental conditions and the reactions of the skin to these, skin infections and toxic manifestations from internal or external causes. A certain amount of overlapping occurs in this rough classification, as infection may be superadded to other lesions, and more than one cause may co-exist.

(1) ENVIRONMENTAL CONDITIONS

High temperatures were of course not encountered throughout the whole of a country like New Guinea, but the trying combination of heat and high humidity was present in most areas occupied by troops except on the elevated parts of the ranges. Heat and humidity were accentuated by the wearing of clothing which covered most of the body, and which for durability had to be relatively thick. The beneficial effect of exposure to the sunlight was evident when this was possible, which was seldom, as disciplinary difficulties arose, and the greater risk of mosquito-borne disease had always to be considered. The complements of naval ships in tropical zones suffered similarly, and where combat conditions enjoined the wearing of antiflash gear[3] discomfort was multiplied.

Miliaria rubra, or prickly heat, caused a great amount of discomfort, and there is evidence, both clinical and experimental, that it can be a prelude to further organic disturbances of the skin and of general bodily function. It is thus more than an annoyance. The degree of trouble caused by this rash varied greatly in different individuals. Its popular name is singularly descriptive, since it is not only directly related to exposure of the body to high temperatures, but its chief subjective symptom is rather a curious prickling sensation than frank itching. This was noted

[3] Long gauntlet cotton gloves and a cowl-like covering for the head and neck.

by Fay and Susman in an investigation carried out in a cruiser during a period of action at sea under tropical conditions, during which the average temperature in the ship was 94°F., and the humidity 57 per cent. They found that among the predisposing causes appeared to be age over 30, a fair skin, a large salt intake and exposure to high environmental temperature due to place of work and lack of ventilation of clothing.

A long series of clinical and experimental observations was carried out by Major J. P. O'Brien. With Major S. D. Allen he collected a series of twenty-two soldiers in Northern Territory and New Guinea, who had symptoms of exhaustion, faintness and distress after exertion. Eighteen of these men had *miliaria rubra.* This syndrome was related to lack of sweating on the body. Its onset was slow; as sweating lessened exhaustion increased, and the heart and respiration rates rose. Sweating was free on the head, and fairly profuse on the palms, soles and axillae, but absent from the rest of the body. The skin showed a greyish "goose-flesh" appearance and was dotted with small vesicles. This condition of "tropical anhidrotic asthenia" is undoubtedly the same as the "thermogenic anhidrosis" described by Wolkin, Goodman and Kelley and is a clinical entity. Allen and O'Brien obtained samples of the affected skin by biopsy, and found histological evidence of blocking of the sweat ducts. This work was later followed up by O'Brien in Merauke and elsewhere, and his researches were embodied in a summary distributed to the A.A.M.C. in 1944 and published fully in 1947. He regarded *miliaria rubra,* tropical anhidrosis and anhidrotic asthenia as three phases of a single disease process, of which the essential anatomical feature is blockage of the sweat ducts. O'Brien further suggested that there might be some sequential relation of this condition to tropical dermatitis. Histological studies on some 2,000 sections from forty skin biopsies showed the formation of a sebaceous plug which blocked the sweat duct, causing it to dilate and rupture, thus explaining anhidrosis and vesicle formation. On this hypothesis *miliaria rubra* would be regarded as the acute stage of a process which may go on to a chronic stage causing lack of sweating and perhaps systemic effects if adaptation did not take place. The degree of blocking of the sweat duct appeared to depend on the sebaceous function of the skin; if this was deficient, especially in the *stratum corneum,* the individual should be prone to prickly heat. Further loss of sebaceous secretion of the skin apparently caused a keratin ring to form, closing the orifices of the sweat ducts. Experiments showed that *miliaria rubra* could be produced in normal subjects by the use of fat solvents on the skin. Further, the use of lanoline could free the obstruction of blocked glands and restore sweating. O'Brien contended that the lipoid content of the *stratum corneum* would depend on the amount of sebum produced by the sebaceous glands, the amount removed by external influences and the amount re-absorbed by the skin. Lipoid might be removed by attrition of clothing, and by the application of soap, especially with hot water, by powders, which acted by adsorption, and by lotions and solvents like alcohol.

On theoretical grounds the preventive measures suggested were that (1) soap should not be used more than once daily on the body in the tropics, (2) that powder should not be used except in the axillae and groins, (3) that the effect of soap and alkali remaining in underclothing should be avoided by rinsing, and (4) that a weekly inunction with fat or lanoline be used. To remove occluding plugs from the sweat glands the use of 10 per cent salicylic acid was suggested, but subsequent trials have cast doubt on the advisability of treating the skin with so strong an agent except with caution. Fay and Susman suggested that scrubbing with soap should free the blocked glands, but O'Brien's experience was that this was quite ineffective, as well as being undesirable. Incomplete forms of this syndrome were stated to recover, but complete forms were found to be disabling, producing some of the features of heat exhaustion. Transient amaurosis and "blackouts" occurred, also vertigo, frontal headache, palpitation, dyspnoea and, in severe cases, anxiety. O'Brien suggested that the response to fats such as anhydrous lanoline should be tested in these complete forms. Further details of this work concerning systemic signs and symptoms will be found in the special section on environmental conditions.

This work was of importance as it had a background of anatomical and physiological investigation, and its observations were made partly in the laboratory and partly in the field.

The question of soap, the method and frequency of its use and its issue to soldiers gave rise to a deal of discussion. On 11th April 1945 a technical instruction was issued by D.G.M.S., Army, on "Preventable casualties from skin lesions". This, besides describing general precautions, dealt with the use of soap, which was necessary for personal hygiene, but was advised to be used in moderation both on clothes and on the body. Some time before a long argument had gone on concerning the issue of soap. In November 1943 the D.G.M.S. had recommended to the Adjutant-General that toilet soap be issued to further hygiene and prevent skin disease. Financial objections delayed the approval of this measure, and even by September 1944 only modified approval had been given for issues of soap to troops in New Guinea, but not those in other areas, such as Northern Australia, where skin diseases were prevalent.

It will be seen that considerable efforts were made to further preventive knowledge of skin disease in the tropics, and its application, but this was chiefly through the energy of individual officers, and the need for investigation on a wider scale was apparent. Meanwhile a great bulk of clinical observation was made by dermatologists. Though *miliaria rubra* was the commonest lesion of the skin due to environmental cause, it was not responsible for serious disability except insofar as it might be a prelude to severer lesions. Of other environmental conditions sweat eruptions, already mentioned, were frequent and important in the islands. Vesicular eruptions were common on the hands and feet. Recurrent cheiropompholyx, common in the Middle East, was much more common in New Guinea, and was surely related to disordered sweat function.

Another condition productive of considerable incapacity was a livid hyperhidrosis of the soles. This was most common among men in tropical areas who had much marching or standing to do in thick socks and heavy boots. Sharply demarcated plaques were seen on those parts of the soles subjected to most pressure: these had a thick sodden whitish centre, often showing a reticular honeycomb-like marking, and were slightly raised at the borders and of a violaceous colour. The lesions were usually symmetrical, involving the plantar aspect of the heel, the side of the sole, the pad over the anterior transverse arch and the plantar surfaces of the toes. The livid border sometimes extended to the edges of the sole and on to the lateral and medial aspects of the heel. The condition was often quite painful and prevented marching and sometimes necessitated regrading of the soldier. Unfortunately men in this category were sometimes energetically treated for tinea with unhappy results.

Scrotal dermatitis when seen was often of chemical origin as will be later described: it was not related to the avitaminosis seen in the men of the 8th Division. Another localised form of dermatitis was *otitis externa*. This is described in the section on ear, nose and throat. This sometimes spread to the pinna and surrounding skin, and formed a troublesome raw and weeping area.

More widely spread dermatoses were frequent, and the speed with which weeping lesions developed and spread made them of great importance. Many were thought to be of toxic origin, particularly those due to sensitivity to certain chemical substances, including external irritants from plants, though these were rare, and drugs like acriflavine and sulphonamides. Even though an original cause was known or suspected, under local conditions the lesions were very resistant to treatment, suggesting that even if sensitivity was present, and even if its causes were removed, resolution of the inflammatory trouble was slow and reluctant. This applied both to circumscribed and generalised conditions, which frequently necessitated evacuation of patients. As in other areas, confusion with tinea or complication of tinea by eczema often led to the incautious use of fungicides and strong antiseptics which made the condition much worse. X-ray treatment was frequently found to be helpful and the provision of facilities for this at base and in some forward base areas was justified by the results.

It is not inappropriate here to refer to exfoliative dermatitis. Exfoliation is of course only a descriptive term, indicating a particular type of severe skin reaction. These serious forms of generalised dermatitis were not infrequently associated with infection, and appeared to be due to it on occasion. But skin infection, if present, was usually a complicating factor, due to streptococci, and sometimes responded well to specific treatment. Probably exfoliative dermatitis was due chiefly to toxic or allergic causes. On every front patients were occasionally seen with this condition; most of them were seriously ill, and some died. Further discussion is best deferred till toxic causes are considered.

(2) INFECTIONS OF THE SKIN

Fungus infections were undoubtedly more common in New Guinea in some areas reaching one-third of all admissions to hospital for skin disease. This was related probably to climatic factors in part, and in part to the existence of numbers of kinds of parasitic fungi in these islands. Generalised *tinea circinata* of the trunk was common. It responded well to early treatment, though it was often complicated by pyogenic infections unless promptly handled. The uncomplicated lesions were usually scaly and dry, discoid in shape, but nodular lesions were seen also, which often were pustular. The beard area was sometimes affected by tinea and occasionally the scalp. *Tinea imbricata,* not very infrequent among New Guinea natives, did not occur among troops.

Tinea cruris occurred, but most of the alleged tineal lesions in this region were intertriginous in nature, and complicated by chemical dermatitis. Despite advice not to insult the scrotal skin with strong dye antiseptics or other fungicides, medical officers sometimes magnified the lesion by such heroic measures. It was of sufficient importance in 1944 for the D.D.M.S. of New Guinea Force to send a special report to headquarters. Tinea of the feet was probably quite common among forward troops: whether or not this was related to discoid eczema of this region there can be no doubt as to the evil effects of over treatment.

Though mycotic infections were common in New Guinea bacterial infections were more frequent and more important. Exposure to the sun favoured a drier skin, and produced tanning, which minimised the incidence of prickly heat and other sweat lesions, and lessened the constant irritation of clothing. Where this measure was possible, and where clothing could be boiled, and where ample facilities were available for bathing, less trouble occurred. The influence of clothing was well seen in one experiment on Bougainville where the men staffing a hospital holding over five wards of skin patients were allowed to discard gaiters for one month. Skin conditions affecting the lower parts of the legs decreased in number from 105 to 17 in this period. The types of pyogenic infections seen were impetigo, folliculitis, furunculosis, and ulcers of the type seen previously in other theatres of war. Suppurative infections of the sweat glands, especially in the axilla, sometimes occurred causing considerable disability. A septic process sometimes invaded deeper tissues, causing cellulitis, with or without abscess formation. The tendency for similar types of infection to occur in groups was illustrated by a report of a number of cases of cellulitis related to surface infection in a naval ship at sea.

Acne vulgaris aroused interest in all Services. Medical officers were reminded in army and air force technical instructions that treatment was not always necessary for a condition that looked worse than it was. But under tropical conditions acne frequently flared up into acute pustulation. Though treatment of the suppurative complications gave relief, and though a good response could usually be obtained by X-ray therapy, these complicating lesions usually made a man unfit for front line service. Their

degree and distribution were often beyond ordinary experience on the mainland; nodulo-cystic lesions were often widely spread over areas usually exempt. It has been suggested that in addition to the overaction of sweat and sebaceous glands, the drinking of chlorinated water may have caused irritation by excretion. Surgeon-Lieutenant S. A. Sewell reported improvement in men with *acne vulgaris* in the tropics treated by insulin. From 1940 to 1945 a series of twenty-eight men were so treated at sea or in shore establishments, and five others in a temperate climate. He reported that active symptoms disappeared usually within a month, but recurrences occurred.

In the treatment of suppurative skin infections sulphonamides applied locally appeared to benefit some if used for a few days only, but wet antiseptic dressings were safer and more effective, avoiding the real risks of sensitisation. Experience forced many medical officers, especially dermatologists, to the dogmatic view that local sulphonamide therapy should not be used in dermatological practice. Penicillin was extensively tried for pyococcal skin infections, and gave excellent results in some. As all the organisms causing these infections are not penicillin-sensitive, failure to respond was noted with others, and relapses occurred too. In the acute stages of furunculosis and the severe long standing types of *sycosis barbae* good and rapid results were obtained.

There were several types of so-called "tropical ulcer" seen in the islands. One type had previously been described in the islands before the war, due to spirochaetal infection. This was not a feature of the ulcers seen in soldiers in New Guinea, where the usual bacteriological finding was a haemolytic streptococcus. Double infection by streptococci and staphylococci was not uncommon, as in the Middle East. The exciting cause of an ulcer was no doubt trauma, however slight. Even scratches and "mokka" bites allowed infection to gain a hold. In these mixed infections there is some bacteriological affinity to symbiotic cutaneous gangrene, such as is occasionally seen after surgical operations. Though the severity of the lesions is incomparably different, it may be that the difference lies rather in the soil than in the seed. Even in these relatively benign infective sores there is some suggestion of the same process early, round which evidences of skin destruction and undermining may be seen. The seriousness of the lesions produced by such infections must depend in part on general and local resistance. This was shown in the experiences of the 8th Division in Burma and Thailand, where the most extensive and dangerous ulcers were produced, which destroyed both limbs and lives. Here the environmental conditions were shocking and the nutrition of the men fell far below any reasonable standard. This condition is more fully described in an earlier section. It is possible that some nutritional factors may have been significant in the Pacific Islands, but it must be remembered that tropical ulcers did not only occur in forward areas. As in other theatres of war, diphtheritic ulceration was seldom seen, but in view of the doubtful aetiology of some of the neuronal palsies seen from time to time it is

perhaps legitimate to wonder if this infection did not sometimes elude recognition.

Impetigo of the bullous type was prevalent and troublesome. It frequently followed *miliaria rubra,* and sequels were not uncommon, the infection spreading deeper into the skin structures, causing boils or sweat gland abscesses. Careful treatment was as a rule effective, but relapse was prone to occur.

Prophylaxis had an important place in treatment, and included the discouragement of insect repellents, personal cleanliness so far as this was possible, and care of all areas of damaged skin. Over energetic treatment was a potential menace, and for these lesions, as for those masquerading as tinea, the use of strong applications like triple dye was discouraged. Occlusion by elastoplast, often used with success in the Middle East, lost favour; it often induced sensitivity and was most unsuitable in this hot and sweaty climate. Captain Jolly reported success during the late stages of the war with antimony compounds given intravenously. Three millilitres of 2 per cent solution of tartar emetic thrice weekly gave good results in the treatment of thirty-six patients and in seven cases dramatic response was claimed. Equal success was not attained by some other observers. Penicillin, 500 units per gramme of base, used as an ointment gave good results. As too did tyrothricin, a small supply of which was obtained by Belisario from the discoverer, Professor Brainerd of San Francisco.

(3) ALLERGIC AND TOXIC STATES

Though this classification overlaps many of the types described as related to environmental conditions, it is convenient to consider them in one group here.

Generalised and exfoliative dermatitis have been briefly discussed in connection with the common widespread forms of skin reaction. It seems likely that sensitisation was responsible for the local and general reactions and rapid spread, by analogy with some of the generalised erythemata. Sometimes it followed a proved streptococcal infection of localised nature, and erythematous or urticarial reactions were followed by more violent disturbance of the skin, leading even to exfoliation, but a chemical factor was undoubtedly responsible in many instances causing an explosion after previous sensitisation. One of the probable causes was one or other of the sulphonamides. Rarely generalised dermatitis occurred in the course of the so-called "tropical lichenoid" which was also of toxic origin.

Though such severe manifestations were fortunately not common, sensitisation rashes of lesser grades were often seen. Sulphonamides caused many of these, chiefly erythemato-papular rashes, following external application to the skin, and skin tests with the drug and even oral administration produced sharp reactions. Though sensitisation did not appear to take place readily if the drug was applied for only a few days, at the most not exceeding five days, the technical instructions issued in April 1945 warned that sulphonamides should not be used at all for local appli-

cation except when the patient was under observation in a general hospital, and then only in special circumstances. The risk in chronic dermatoses was recognised to be much greater and lamentable results have been observed. Other and safer remedies gave equally good results in infections of the skin; perhaps the anatomical and pharmacological differences between wounds and burns, in which sulphonamides can safely be applied with care, and other lesions of the skin were not closely recognised by all.

Acriflavine was another chemical source of sensitisation; its use required caution and prolonged use was discouraged. A technical instruction (No. 93) directed that acridines whether in powder or solution should not be used for more than five to seven days. Sensitisation to acriflavine was sometimes seen in men who had become also sensitive to sulphonamides.

Some sensitisation to uniforms was suspected in the later stages of the war in some forward areas; most of the issue uniforms then used were of "jungle green", whose green dye was believed to be harmless. Some earlier issues had originally been dyed with chrome, but whether these were really to blame is uncertain, as there were so many influences which might initiate or increase sensitisation.

Contact dermatitis was caused in susceptible persons by several botanical irritants. A number of plants in Northern Australia are known to cause irritation, such as the "Gympie tree" and the "tar tree" in Queensland. A few men were affected by this, and from Northern Territory English and Gray also reported cases of sap dermatitis due to the wild fig in which erythema and vesiculation were caused. It may be that more contact irritation from tropical vegetation occurred than is known. A phyto-photo-dermatitis due to parsnips was also proved to occur in susceptible men in contact with these vegetables, usually in kitchens. In May 1943 some severe bullous reactions observed on the skin of men in New Guinea aroused attention, and the question was raised of its being due to mustard gas dropped from the air. Colonel Belisario at the 2/5th A.G.H. proved that parsnip substance, in the presence of moisture and sunlight, was the cause. He produced the eruption on volunteers exposed to sunlight with parsnip scrapings applied to the thighs. The seeds, skin, leaves, core and pulp were all effective, in that order. The lesions produced were erythematous, and bullous if the exposure to the irritant and especially to solar radiation, soon after contact was sufficient in degree. A technical instruction was later issued in which precautions were advised —care to be taken not to peel or prepare parsnips out of doors, and not to court prolonged exposure to the sun of the skin of the arms and hands for 24 hours afterwards. This phyto-photo-dermatitis also occurred in the air force, officers in a Flying Training School at Uranquinty, in New South Wales, being affected after gathering parsnips in a garden. Contact dermatitis occasionally was produced by other animal or vegetable agents.

Other medicaments causing dermatitis were antiseptics in medicated soap, and "Novocain". The last mentioned was responsible for considerable trouble in dental officers. Some of the most difficult problems arose with officers and men whose hands were necessary in varieties of skilled

work; a sensitisation dermatitis of the hands is a relentless kind of complaint. Tetryl dermatitis was observed by Murray, Prunster and Anderson in Australian munitions factories, in workers filling fuses. The risk was greatest in the first two or three weeks after this work was begun. Cases were also seen in the Royal Australian Navy in men handling ammunition. In the R.A.A.F. contact dermatitis arose sometimes from the use of solvents and cutting agents. Some of these lesions were acneiform, others eczematous.

THE LICHENOID DERMATOSES

The most important form of skin lesion due to toxic or allergic action of a chemical substance was undoubtedly the so-called "tropical lichenoid". This has been described briefly in the section on malaria. The term "tropical" was originally selected as a neutral one, though "toxic" would be more appropriate. Commendable restraint was shown in publication of descriptions of this disease, for it was observed by Australian medical officers for some two years before any definite opinions were expressed about it. As pointed out elsewhere, the integrity of malaria control depended upon atebrin, and had the faith of the forces been shaken in this mainstay the issue might have been endangered. The small percentage of cases (about 1 in 2,000) justified silence, and the military value of atebrin was never imperilled by this fortunately uncommon dermatosis.

In 1943 observers all over the malarial zones began to notice chronic eruption of the skin whose appearance and distribution suggested *lichen planus*. At that time the number of troops taking full suppressive doses of atebrin was somewhat limited, but as campaigns involved more men and lasted longer and were fought in hyperendemic areas the incidence of this rash increased. With extension of atebrin suppression to rest periods and adoption of "chaser" courses of the drug after clinical attacks of malaria the amount of atebrin taken also increased. It is doubtful whether all the appearances described in the literature were truly attributable to this dermatosis. Dermatitis was common from a number of causes, and co-existence of this with the lichenoid rash could complicate the clinical picture. Proof of the association of lichenoid with atebrin is now generally accepted, though patch tests were inconclusive as a means of proof. It did not occur in the South-West Pacific Area except in persons taking atebrin, and not in any who took less than the usual suppressive dose of 0.1 gramme daily. Dosage over a period of at least 2 or 3 months was necessary before it appeared. In other tropical areas where there was no malaria and therefore no atebrin was taken it did not appear. It is possible that other conditions may have contributed to the production of this lichenoid eruption in persons with an idiosyncracy to atebrin, such as climate, clothing, nutrition and bodily and mental attrition in difficult country. It is, however, noteworthy that cases appeared under good conditions at a time when the affected individuals were in non-malarious areas but still taking atebrin.

There was no special sex incidence; both males and females were affected. Occupation had no influence, and forward and base troops were equally affected if they were taking similar doses of atebrin. More cases came at first from forward areas, but this was due to the greater number of men there on full suppressive doses.

The mode of onset varied. Itchy purplish spots might be noticed, or thickening of the palms and soles, with some tender fissuring. It is interesting to recall that thickening of the skin of these parts had been noticed for some years previously in persons taking atebrin in different parts of the world. Another type of onset was the appearance of thick papules, followed on occasion by acute generalised or exfoliative dermatitis. In others a painful excoriation appeared on the eyelids: here again it is of interest that localised lesions on the eyelids were noticed in dermatological wards without any causal relation with atebrin being suggested, though this was quite possible. Sore whitish patches in the mouth were sometimes an early symptom also. More will be said presently about the early signs.

In the declared eruption the characteristic lesions were firm flat papules of violaceous colour, at first soft, later becoming hard and nodular. Plaques were common too, and by way of contrast, rough follicular spines appeared sometimes. The skin was somewhat reddened, and the background of yellow pigmentation by atebrin produced a purplish hue of varying tint. The general tendency of the eruption was atrophic, though hypertrophy of lower grade levels of the skin were common. Thus greyish mucous patches were usually seen in the region of the mouth in about a third of the patients. These might be seen on the lips, the buccal mucosa, the tongue, and in addition sometimes on the urethra and anus. Denudation of mucous patches sometimes occurred, causing discomfort or even pain. Linear discolourations of a slate blue to a violaceous tint were often seen on the eyelids and in the centre of the palate also. Lesions were found on the scalp with some atrophic alopecia: here and elsewhere the atrophic lesions did not always completely return to normal when the rest of the eruption resolved. Dystrophies of the nails were also seen.

Bare areas appeared on the skin in severe cases of this dermatosis, with erosion and granulation. Hypertrophic lesions took the form of simple thickening of the skin, which in some persons was considerable. Simple papillomata might appear anywhere. In the more severe cases hard warty outgrowths appeared, and after a time large pigmented masses of hardened epidermis formed. Occasionally these became deeply pigmented, even quite black, for instance on the lower parts of the trunk. A typical distribution in an established eruption showed purplish scaly lesions on the eyelids, scattered plaques on the scalp, leucoplakic lesions in the mouth, papular lesions of the upper part of the trunk, tending to point circumferentially, harder plaques or warty lesions of the lower part of the trunk and buttocks, and violaceous nodules on the limbs, chiefly aggregated round the ankles, elbows, wrists and knuckles. This description, agreeing with that of Schmitt, Alpins and Chambers conforms in general with the Australian observations. Exudative characters appeared in numbers of

instances of this dermatosis. In regions like the axillae, groins, and behind the ears, weeping eczematised lesions were often seen. Itching was a frequent feature of the rash, and scratching soon denuded the atrophic epithelium. Intertrigo and eczema have been described as representing one type of this eruption, but it seems preferable to regard these as a result of the essential pathological changes in the skin rather than as a feature of a description of the characteristic lesions. Most of the descriptions deal with the established rash, but as experience grew the character and distribution of the early lesions were recognised as suspicious.

Though itching varied in severity in the early manifestations of the disease, it was a common early symptom. At this time lesions were noticed on the inner aspects of the fingers, palms, soles, and to some extent the arms and thighs, and also the middle of the body. These were red and scaly, and soon became slightly raised, and thus assumed a lichenoid character.

The general symptoms of the dermatosis were chiefly those associated with discomfort due to itching. In a few instances more severe and serious somatic affections occurred. A generalised "tropical lichenoid" dermatosis was associated rarely with a fatal hepatitis, as in the case described by Lum, and aplastic changes in the blood were observed in a few cases.

Histological study of the skin showed hyperkeratosis with plugging of the ducts of keratin, with atrophic epidermal changes in places. Focal collections of inflammatory cells were seen, and the basal cells contained pigment in varying amount. On the whole the appearance and to some extent the distribution of the skin lesions and their cellular characters on microscopic section were strongly reminiscent of *lichen planus,* yet from the beginning dermatologists felt that this dermatosis was an entity. Once the process had begun it was slowly progressive while atebrin was taken. Occasionally an attack of malaria was treated with atebrin in a patient with this dermatosis without any apparent effect on the skin condition, but in a condition so chronic such observations are probably not significant.

The course of this malady of the skin was slow. Patients treated early might recover completely in three or four months, but a year more frequently elapsed before resolution was reasonably complete. Clinical improvement usually began when the characteristic yellow atebrin pigmentation began to disappear. Where dark pigment had been deposited in the thickened skin it often persisted long after the skin had cleared. No special treatment was found of any value. Relief from itching was welcome, by the use of the usual applications, as it favoured rest and sleep and minimised excoriation and eczematisation of the skin. X-ray treatment gave some relief in this direction and helped to resolve the raised lichenoid lesions. Vitamin *A* and *B* complexes were tried therapeutically but without result. Patients with this dermatosis were considered completely unfit for further service in forward areas or those where atebrin was taken for suppressive purposes.

Atebrin was responsible also for some curious pigmentation of the skin. Though it was often said that the conjunctivae were not pigmented

by atebrin, this was not true. The colour was distinguishable from jaundice, being more greenish yellow. There was indeed a certain bluish component in the colour when it was deep, and this was well seen in a few individuals in whom a bluish-grey colour was noted in the skin of some parts, particularly the nail plates of the hands and feet, the alae and the tip of the nose, and also on palate and epiglottis. This was slow to disappear, and like the occasional deeper atebrin pigmentation, did not vanish till after six or nine months.

OTHER CONDITIONS

Mention must also be made of some of the less urgent and less common affections of the skin. An instruction was issued in 1943 pointing out that certain dermatoses were of minor military importance and seldom warranted sending a soldier to base. Such were *rosacea,* which was seldom a disability; psoriasis, usually existing before enlistment and only a serious disability if it became eczematised, though often a cause of some distress, and actually a good reason for rejection for frontline service; warts, except on hands or feet, and vascular naevi. Hyperkeratoses in older men were considered as a cause for special treatment only after consultation with a surgeon or dermatologist. With regard to plantar warts these were of course an important disability, but did not warrant the sending of men back to hospital as they could be dealt with in areas where simple surgical methods were feasible. The methods adopted were usually such as described in the R.A.A.F. technical instruction on the treatment of skin disease. The callus could be removed after the application of a salicylic plaster or by curettage under local anaesthesia. Where available X-ray therapy was also used with good results.

Of the less common diseases, cases of chromoblasto-mycosis were described by Hicks, and by Saxton, Hatcher and Derrick, a mycotic infection already known to occur in parts of Australia, of long duration and causing red scaly and warty lesions. A case of larva migrans, a form of cutaneous myiasis, was described by Hughes. *Dermatitis herpetiformis,* though uncommon, was occasionally seen. Response to sulphonamides often was favourable, but the disease was an indication for discharge to civil life. Colloid degeneration, a very rare disease, was seen in a small number of cases, suggesting a greater frequency than on the mainland of Australia. Murray Will had the unusual experience of demonstrating *molluscum contagiosum* at a hospital clinical meeting, and finding afterwards that three medical officers in the audience also had typical lesions, of whose nature they had been unaware.

THE PROBLEM IN 1945

In the early part of 1945 the admissions to hospitals in the tropical areas for dermatitis were so high that efforts were made to attack the problem from the points of view of education and research. Colonel Belisario compiled a brochure on diagnosis, prevention and treatment of skin diseases in the tropics, which was distributed to forward areas by

New Guinea Force. A booklet giving instructions on the methods of prevention and treatment was compiled in the First Army area by Major Perkins, Dermatologist to the 2/7th A.G.H. It was widely recognised in the area that further facilities for treatment and prevention of skin disease were urgently needed, and suggestions came from a number of army hospitals and headquarters. A recommendation was made by General Burston, D.G.M.S. in January 1945 to the Master General of Ordnance that three sets of clothing should be issued to all men in operational areas. It was evident too that some coordinated plans for research were necessary. The improvement of skin conditions under lowered external temperature was so clearly recognised that the possibilities of treatment in air conditioned wards were explored. With the help of engineering services some degree of air conditioning was achieved in a special ward at Lae, and here patients with acute conditions of various kinds, including some diseases of the skin, were treated with success.

The evacuation of a large number of men with skin diseases to the mainland had obvious objections, as some of these would be certainly lost to the Services for longer periods than if they could be efficiently treated at forward bases. In Australia base hospitals held many patients with skin complaints, and the setting aside of a considerable section of the medical division of the 114th A.G.H. at Goulburn for this purpose, where psychiatric patients were also held, was of great value, as the climate was much cooler than in many base areas.

At advanced land headquarters at Morotai, the D.D.G.M.S., Brigadier W. P. MacCallum, drew up a statement of the position and brought forward suggestions. He pointed out that at this time, May 1945, skin disease was the largest single cause of casualties in the A.M.F. The figures showing rates per 1,000 of average yearly strengths may be here interpolated to show the magnitude of the problem.

Year	Rate in A.M.F. in Australia (to nearest integer)	Rate in A.M.F. in S.W.P.A.
1943	49	53
1944	65	80
1945	63	105

From 1939 to the end of 1944, 3,295 soldiers had been discharged from the army because of skin disease.

Some reduction of this rate was found possible by adequate instruction of medical officers and orderlies, and the taking of preventive measures in all units. But in spite of definite advances in the effectiveness of dermatological work, there still remained an extensive field in which planned research work should produce good results. Some research had been carried out in various centres, but this was not coordinated or broadly planned. A recommendation was therefore made that a small research group should be formed, consisting of a dermatologist, a pathologist, a technician, a clerk and a batman. This would be self-contained, and could be located at a base hospital in an army or corps area, where a scheme

of investigation could be laid down after discussion with the consultants. The importance of basic research was recognised; *miliaria rubra* for example had been proved to be of great importance, and the relationship of its pathological processes to more extensive infective or sensitisation lesions needed further investigation.

Fundamental questions required answer, such as the comparative frequency of skin disease in men and women, and in Allied and Australian troops, the effect on the skin of the use of reducing compounds or soap in washing clothes, the effects on the skin of hot showers, and of soap. Further investigations in the field of bacteriology, histology and mycology were also necessary. A further suggestion was that a series of centres was required for observation and treatment of skin disease under controlled directorship, and in addition field experiments should be planned.

By the beginning of August some definite planning had been made by collaboration of a consultant physician and a dermatologist with the Director of Medicine. It was proposed to carry out experimental work in pursuance of O'Brien's previous researches, to test the bearing of defatting of the skin on dermatitis, especially in relation to details of bathing hygiene, and also to attempt to produce experimental lesions by contact with affected patients. Clinical studies would also be carried out, in order to obtain all possible information about the nature and natural history of sweat disorders and sensitisations and infections of the skin and their connection, if any. A complete dermatological survey of several forward units was planned to gain information on the influence of tasks, modes of living, clothing *et cetera* on skin disease. This extensive project was planned too late to be put into effect, for within a few weeks the end of the Pacific war came.

CONCLUSION

Although organised research did not have the opportunity to establish more of the basic principles of the physiology and pathology of the skin in the tropics, some general conclusions were reached. Many of the disabilities of patients treated would not be serious in civil life, but in military surroundings they could be troublesome. The difficulty of reversing a pathological state of the skin under these conditions was great. Early treatment was essential in dermatological conditions, but the correct treatment was not always easy to apply. To choose apparent inactivity of treatment is to impose a psychological hazard in a forward area, and to apply frequent mild wet dressings is often impracticable and invites the use of an unsuitable but easily applied preparation such as an ointment. Oily or greasy preparations were most unsuitable for routine use in the tropics, whether a first or last thought they were often an unhappy choice. The dangers of heavy metals, even in the apparently harmless zinc preparations, were often not realised.

Conditions of transport in the South-West Pacific Area were such that it was usually impossible to obtain adequate supplies of all desired materials for treatment. However, it must be admitted that even allowing

for all the difficulties, junior medical officers being prepared for military service have educational needs rather different from those which shape their tuition under ordinary conditions. It might even be that these considerations might equip them better for civil practice too. The famous remark about Lister's arguments for antisepsis becoming stronger as his solutions became weaker might perhaps be remembered by all those who have to treat already insulted skin.

Skin disease in armed forces at war results from a number of traumata applied to the most neglected organ of the body, the integument. In tropical warfare its misused function of sweating is overloaded; its vasomotor system is sorely tried by influences from the cerebral cortex down to the skin capillaries; it is injured by mechanical, thermal, chemical and infective agents; and its resentment is not unnatural. The importance of mental influences on disorders of the skin, mentioned at the opening of this account, was often evident in military dermatology.

A certain amount was achieved. Endeavours were made to lessen the assaults on this sensitive covering, usually unprotected even by pigment, and technical methods were selected and applied with care. X-ray therapy proved a useful adjunct, practicable at a forward base, lessened sensitivity, and shortened the time of illness. The official addition of trained dermatologists to hospital staffs was most valuable. More perhaps might have been done in the educational way by using a whole-time mobile consultant chiefly for this purpose, the work done by dermatologists acting semi-officially as regional consultants was most valuable.

Few men died from primary affections of the skin, but the rare deaths from exfoliative dermatitis showed its serious potentialities. Recovery has been complete in most of the maladies of the skin, and even the occasional aftermath of increased dermal sensitivity should dwindle with the passage of time.

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CHAPTER 56

EAR, NOSE AND THROAT

EAR, nose and throat surgery in the Services has followed the lead of this specialty in civil practice and at the beginning of the war was firmly established as a necessary part of the surgical activities of hospitals, even if these were stationed at forward bases. It was not long before the rising volume of work showed, not only the need for the specialty in the army, but also the wideness of the mesh of recruiting examination, through which slipped numbers of men with chronic aural conditions in particular likely to give trouble on service.

The acute conditions depended in part on the environment, which, in camps and transports particularly, produced crops of infections of the upper respiratory tract. The severe epidemics of these diseases during the winter of 1940 in the various training camps in Australia were responsible for a number of these, but as the accommodation in these camps caught up with the urgent requirements of mobilisation, the position eased. Most of the work of these epidemics fell on the staffs of general medical wards in the hospitals, but a great number of aural and nasal complications needed special attention. As time went on and more men overseas were engaged in training or action in the desert, a growing proportion of them were seen with other acute conditions of this kind, notably *otitis externa* and the traumatic affections of the ear. *Otitis externa* became really troublesome in the island campaigns. The traumatisms of the ear included those due to blast, either from aerial concussion, from artillery or from bomb explosions, and the important barotrauma occurring in aircrews subjected to considerable changes in pressure through elevation.

RECRUITING STANDARDS

Before passing to the clinical considerations encountered, it is necessary to deal with the question of recruiting standards. In July 1940 the A.I.F. standard required for class I the ability to hear in each ear a whispered voice at twenty feet, and for class II ordinary speech in both ears at ten feet. It was not till 1943 that specific instructions were given to include an auriscopic examination: before this date it was usually made only if the finding of subnormal hearing suggested the existence of cerumen. The ability to hear low or high pitched sounds was tested roughly by the use of words with appropriate overtones, and the standards for hearing were modified to suit the now altered system of classification. At this time, an otologist became a necessary member of the consultant staff required for special decisions in a recruiting centre. Various modifications were made in the detailed instructions, but in the latter years of the war the rulings were as follows: perforation of the drum, aural discharge or a mastoid scar did not necessarily disqualify a man from service; men with

persistent offensive discharge with posterior or superior perforation were classed as unfit, but those with intermittent or continuous non-offensive discharge from an anterior perforation might be class A2 or B unless the otologist considered the condition severe. A dry perforation of the drum was no bar to acceptance in classes A1 and A2, neither was the presence *per se* of the scar of a mastoidectomy. In 1945, a man who could hear ordinary speech in both ears only at a distance of five feet could be accepted for the lowest serving category, B2. No mention was made of otosclerosis, nor was there at any time any direction about examining the nose or accessory sinuses.

INFECTIONS OF CIVILIAN TYPE

It will be seen that it was inevitable that men would enter the forces with various chronic conditions which might deteriorate during service, thus making them eligible for pension rights. These conditions included chronic forms of deafness, suppurative *otitis media,* mastoiditis, sinusitis, and nasal polypi. In the early years of the war this was particularly evident. In Palestine only one hospital, the 2/1st A.G.H., worked fully during the first year and its experience epitomised the position about disabilities of the ears, nose and throat. As well as the acute diseases, such as *otitis media* and sinusitis, requiring treatment in hospital, large numbers of chronic conditions were seen, necessitating a busy out-patient clinic, at which attendances even with a restricted intake were up to sixty per week. In-patients were often over eighty in number, and at times exceeded a hundred. During the war period, numbers of men with chronic nasal or aural disabilities passed repeatedly through forward and base medical units with exacerbations of infections present before enlistment, but army general hospitals found the numbers decreased somewhat in 1944 and 1945, owing to the more careful selection of recruits. This experience has shown that patients with chronic or recurrent suppurative *otitis media* should not be classified higher than B.

Little need be said of the acute states treated, as these follow familiar civilian patterns. In the period 1940-1942, there was no definite agreement on the indications and contraindications for sulphonamides in acute *otitis media,* but some caution was considered advisable, since a fall in temperature and lessening of discharge might mask the onset of lateral sinus thrombosis or brain abscess. Sulphamerazine was used later with good effect for acute sinusitis, and the local application of penicillin was found valuable in some army hospitals, particularly when haemolytic staphylococci were the infecting agents. Penicillin was used parenterally with success in acute sinusitis, but not in chronic infections, even when the organisms concerned were sensitive.

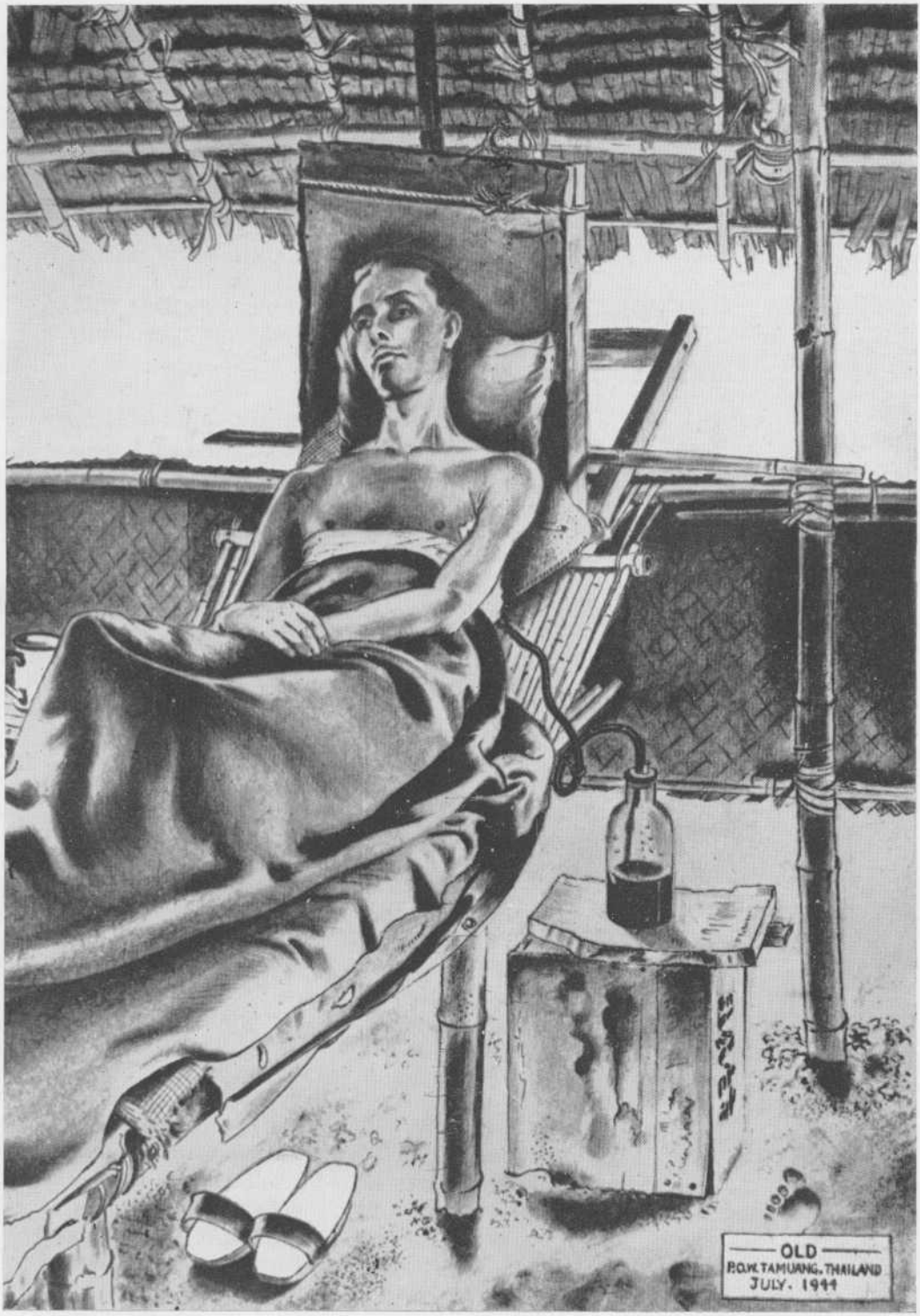
Non-urgent conditions gave some trouble, such as recurrent tonsillar infections, and deviation of the nasal septum. Senior medical officers of some army hospitals expressed the opinion that too many men were referred for tonsillectomy because of some vague "fibrositis", or for septal

deviation when neither condition appeared relevant to the men's health or comfort. A technical instruction was promulgated in 1942 forbidding the carrying out of interval surgery in field ambulances or except by express direction of A.D.M.S. or D.D.M.S., in casualty clearing stations. In 1944, a further instruction expressly stated that nasal septal deviation was not a general disability preventing active service. This statement, though largely true, did not take into account the importance of marked septal deviation in predisposing towards and prolonging sinusitis. It should be noted also that in 1942 a consultant physician informed the D.G.M.S., Army, that chronic paranasal and aural infections were not infrequently overlooked by medical boards.

TRAUMATISM OF THE EAR

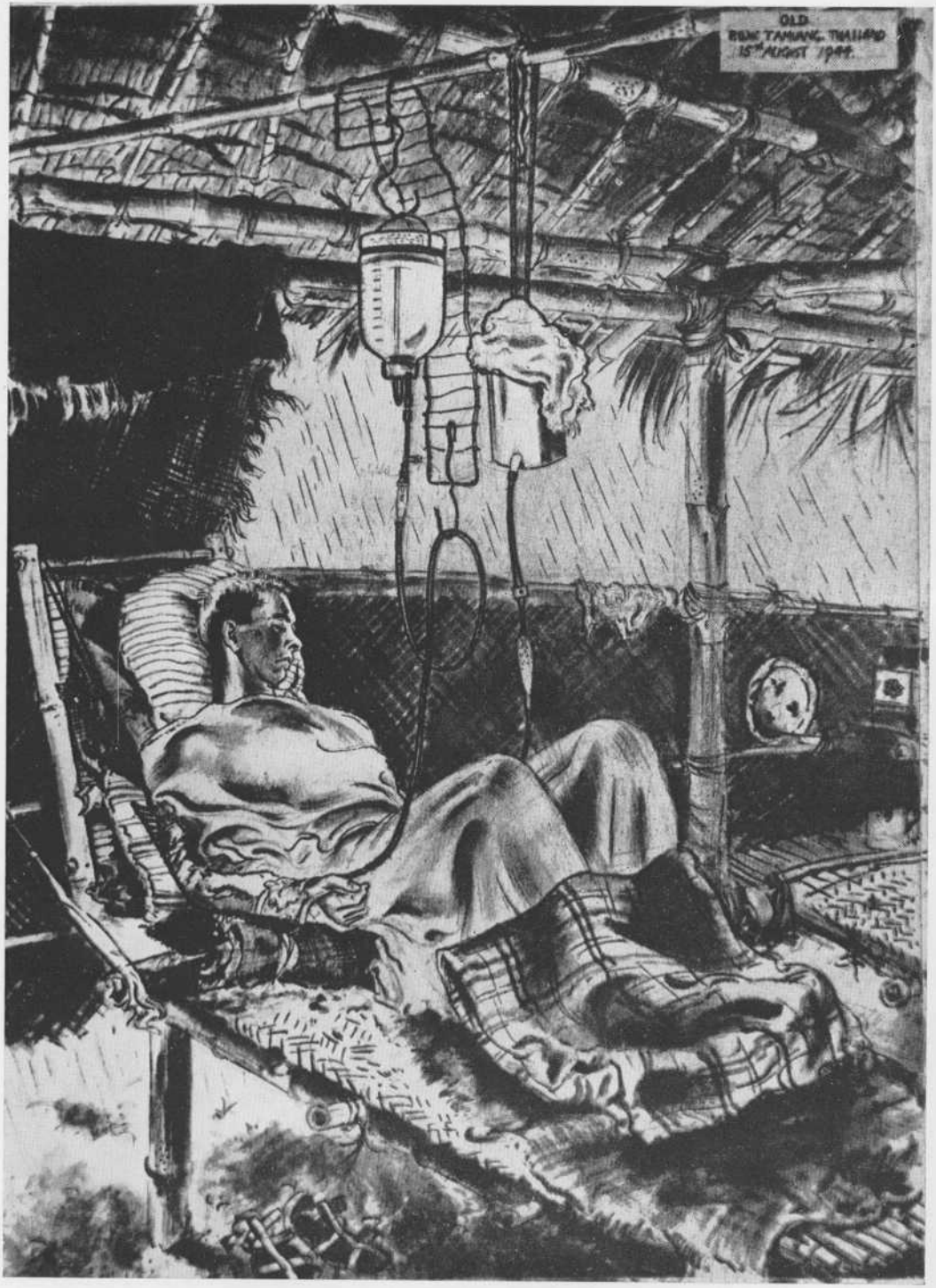
Traumatic conditions affecting the ears were found to be of some importance. In 1941, in Tobruk, perforations of the drum were seen not uncommonly. These were occasionally said to be multiple, but more usually large and single, placed laterally and often, though not always, permanent. Infection there was rare. Both in the 2/4th A.G.H. in Tobruk, and in the 2/7th A.G.H. at the time of the Alamein battle, little loss of hearing was noted, but the possibility of some later disability was recognised, owing to the probability of coincident damage to the cochlea. In the 2/6th A.G.H. in 1942, a larger proportion of secondary infections of the middle ear was observed following rupture of the drum by blast, rising as high as 60 per cent. This has been attributed to the greater prevalence of infective organisms in areas more closely populated than the bacteriologically sterile desert of the 1940 campaign, but it seems likely that infecting bacteria also came from the patient's skin, carried in by blast or by the introduction of drops. Sulphonamides given orally were found to be effective for these infections. In Changi, Singapore Island, after the capitulation a number of cases of "blast ear" were seen with little deterioration of hearing. Though some patients had otorrhoea for variable periods, perforations made little difference in hearing.

The prevention of these injuries was considered. The problem varied in different circumstances. Artillery units and gun crews on ships were able to adopt some preventive devices, and considerable experimentation went on, through which better types of ear plug were evolved; these permitted a useful degree of hearing yet shielded the drum from damage by the waves of compression and rarefaction. Blast from bombs was a different matter, and it was natural that severe damage to the ears might take place under conditions to which the already shielded lungs were vulnerable. The well known vagaries of blast waves were noted in this form of aural damage. Tank crews were particularly susceptible to blast injuries, for instance, if a tank ran over a land mine. Other forms of barotrauma peculiar to airmen are best dealt with in connection with other aviation subjects.



(Drawn by A. G. Old)

Post-operative nursing for empyema, Tamuang, Thailand.



(Drawn by A. G. Old)

Post-operative nursing, using intravenous and rectal saline, Tamuang.

OTITIS EXTERNA

Otitis externa was occasionally seen in the Middle East forces, but was not very troublesome. In Malaya it gave a good deal of trouble: in the Pacific Islands and in Queensland and the Northern Territory severe *otitis externa* was very prevalent among the Australian forces. As is usual it was called by several names, such as "tropical" or "Singapore" ear or "mycotic" otitis; the first of these is the most accurate, as it was not usually due to a fungus. Troops in Colombo found it prevalent, and the 8th Division in Malaya recorded a high incidence, particularly associated with bathing. In Morotai and Borneo it was also common, but in New Guinea the large numbers involved gave opportunity for considerable study and also search for the most effective treatment. Various types and stages were recognised. Technical Instruction No. 62 was issued entitled "Mycotic infections of the ear". This described three stages: (1) with tenderness, but little abnormal to be seen in the canal, except debris and white foamy flecks, (2) with redness and inflammation, of the canal associated with great tenderness, and (3) with swelling of the canal even to the extent of obliteration. Treatment was laid down for each stage. Spirit drops, and "tropical ear drops" containing chloroform, camphor and thymol in paraffin were advised for earlier stages and packing with various solutions for the swollen type of canal. Castellani's paint was also advised. Later this instruction was withdrawn, and No. 123 substituted. In this it was pointed out that there was no unanimity of opinion as to the causative agents, nor was there any specific treatment. In general, cleansing followed by careful *tamponnade* was advised, and patients not responding were sent to hospital. Experience enriched the descriptions of this condition, and revealed considerable differences of opinion in treatment.

The commonest type was the desquamating variety, which made up nearly half of those seen in some large series. A lesser variant of this caused only a dry scaliness of the epithelium of the ear canal. The most intractable type was moist and eczematous in nature; this sometimes lasted six or twelve weeks. A furuncular form was also seen, in which, as in the other severer types, recurrence was prone to occur. The most usual appearance found in early stages of *otitis externa* was a dry red canal, which if untreated became moist and yellow, with sodden epithelium and some discharge. Oedema of the canal was variable; pain depended on the degree of swelling present. When the canal was dry or desquamating the condition was usually not severe enough to be troublesome, amounting to little more than some aching or discomfort on chewing. When inflammatory changes became more severe, particularly when associated with enlargement of the pre-auricular glands, and with swelling so severe as to block the ear canal, pain was often very severe. Inflammation sometimes invaded the surface of the drum also, and when the drum was perforated in addition, the discharge and inflammatory changes were harder to control.

In the 2/9th Australian General Hospital in New Guinea Quayle reported that of 739 in-patients treated in ear, nose and throat wards, 293

had *otitis externa* and 188 *otitis media*: the former accounted for 339 of 1,120 out-patients. In 65 per cent of the cases of *otitis externa P. pyocyanea* was cultivated, and in 16 per cent coliform organisms. He only found a fungus in 4 out of 25 investigated. Quayle observed that the natives had wider and straighter canals than the Australians, and were seldom infected. In an advanced base in New Guinea, E. L. Davis found the *trichophyton* in 11 out of 22 cases. Basil Jones found it in 39 out of 76. In this, as in other series, bacteria were also found. *Staphylococcus albus* was common in patients with *otitis externa* but also in controls. The commonest bacteria found were *P. pyocyanea, Staphylococcus albus* and *aureus* and *Proteus vulgaris.*

Treatment of the milder types was not so difficult. Quayle thought the mycotic variety was easier to cure, but this may be due to the importance of bacterial infection in the severer types. Where a fungus was found Castellani's paint gave good results, and ichthyol in glycerin proved a reliable routine application. Earnshaw obtained good results by packing the canal in the severer infections, so as to compress and separate the swollen walls: this could be done only under morphine or general anaesthesia. This drastic method was not favoured by all. Good results were reported from the repeated use of drops of ichthyol or a mercurial or silver preparation, either with or without a gauze wick. If packing was used it was only for a brief period, usually two days, after which spirit drops and a mercurial antiseptic were used. Watery solutions were not used except perhaps for preliminary syringing to remove debris. Penicillin was used for some of the very acute varieties, and proved effective, though recurrences were seen. Chronic types sometimes responded to the instillation of penicillin, 250 units to 1 cubic centimetre. Here, too, relapses occurred, but could be partly prevented by after care. It was recognised that manipulations in the ear canal, even with a cleaning stick and wool, should only be carried out by the skilled hand. A no-touch technique was recommended in the official instruction.

Preventive measures were important. Bathing in streams carried the risk of infection, especially in New Guinea, where even sparkling clear streams were frequently polluted. Early treatment, using some simple form of ear drops, was of value in preventing severer grades of inflammation.

It is significant that *otitis externa* was so common a cause of disability in the moist tropical climates, for it is really a dermatological complaint affecting a specialised region. Like other maladies of the skin in the tropics, it was a considerable waster of efficiency.

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CHAPTER 57

OPHTHALMOLOGY

THE organisation of an army ophthalmic service belongs to the administrative section of a medical history, but the various advances made may be referred to here, as they were due to clinical experience under military conditions. An ophthalmic surgeon was attached to each Australian general hospital, but the bulk of the work, especially the estimation of refractions, demonstrated the necessity for establishing ophthalmic departments.

When the 2/1st A.G.H. was established in Palestine with the 16th Brigade, the work developed along the lines of a civilian hospital. Equipment for making spectacles in a workshop within the hospital was needed, and in January 1942 Major C. Morlet was empowered to purchase in Cairo this equipment, which later became standard. Three such workshops were working and almost completely equipped when the A.I.F. returned to Australia, and others were likewise established in Australia. The amount of refractive work done was astonishing. At the 2/1st A.G.H., in seven months in 1940, 791 men had their eyes tested for refractive error and 489 needed glasses, and at the end of a year, 1,140 pairs of glasses had been ordered. During the siege of Tobruk Major Morlet recorded that of 300 prescriptions sent to Egypt, only 67 pairs of glasses were returned. Since the only contact with the outside world was by destroyer, which ran the gauntlet of an air attack, it is remarkable that any were received at all.

The existing facilities in Palestine for obtaining spectacles in quantity were poor; frames were unsatisfactory and allowed rotation of cylinders, even when of an army pattern. Later a standard army spectacles frame (Australian pattern A.P. 43) was adopted. Some curious minor difficulties occurred with frames. Metal frames treated with nickel occasionally caused dermatitis, and some non-metallic frames were dissolved by mosquito repellent.

At the beginning of the war the visual standards for recruits of the A.I.F. were those laid down in 1938. These conformed to the old classification of class I and class II recruits, the former fit for active service with field formations. Later, modifications were made when the classifications of physical fitness were altered. Details of the earlier visual standards and their modifications may be found in Volume II. The final standard adopted in 1945, was designed to cover all requirements and not be too complicated for general application. This was as follows:

Class A1 (a) Unaided vision 6/18 with each eye or 6/12 with one eye and 6/36 with the other.

(b) If wearing glasses vision 6/9 each eye provided that unaided vision is 6/24 with one eye and 6/60 with the other, or 6/12 with one eye if the other is less than 6/60.

Class A2 Unaided vision 6/24 one eye, 6/60 in the other, with 6/12 in one eye if the other is less than 6/60 or sightless. The vision of one eye must be correctable to 6/9 by glasses.

Class B2 Unaided vision less than A2, provided that glasses improve one eye to 6/12 or each eye to 6/18.

In the early days of recruiting some of the eye examinations were not satisfactory, owing to lack of staff and facilities. Several men with an artificial eye actually succeeded in passing a hurried examination. Later, eye tests were usually made by one medical officer only, who supervised the whole examination personally, and the services of a consultant were readily obtainable. In 1945, all recruits were examined by an ophthalmologist before enlistment and where the vision was lower than 6/12 the condition causing the defect was entered on AAF D1. No recruit with a progressive lesion was accepted for service. A note was made in the soldier's record of service book if he was sightless in one eye, and if the vision was below A1 standard, the record service book read "vision unfit for M.T. driving".

Learners in ophthalmology who were specially interested in this work were approved in the latter stages of the war. They were attached to a civilian eye hospital for six months, and to a base military hospital for a further six months, and were then posted to an army general hospital. An adviser in ophthalmology was appointed, and later a consultant attached to the general headquarters in Melbourne, who directed the work of this branch of the medical services.

Another important advance in the ophthalmological branch of the medical services was the creation of an establishment for commissioned officer optometrists. At the outbreak of war most of them served in fighting formations as privates. Some served in hospitals with the rank of sergeant, and assisted the ophthalmologist and in refractions and other routine work. In 1942, with the setting up of optical workshops in general hospitals, a lieutenant optometrist became an integral part of this organisation, with specialised duties.

AFFECTIONS OF VISION

Standards were the subject of a good deal of argument during the war, particularly when military conditions were changing. Difficulty was occasionally found in placing individuals accurately. At the end of the war when nutritional amblyopia was commonly seen among prisoners of war, it was evident that the presence of scotomata could handicap a man functionally, even in an emmetropic eye, more than a considerable refractive error. This subject is dealt with below.

With regard to refractive errors, care was taken not to prescribe spectacles for minor aberrations. A technical instruction directed the attention of medical officers to the great shortage of optical material and pointed out that spectacles were to be prescribed only for the efficient performance of duty or for relief of symptoms due to refractive error. Men of the 1939-1945 war appeared to be more "eye conscious" than those of

1914-1918, and their zeal in having small errors investigated took up much of the ophthalmologist's time. The number of presbyopics was also considerable. In the brilliant light of Palestine it was found that eye discomfort and headache were often associated with a refractive error, whose correction relieved the symptoms without the aid of tinted glasses. In 1941 a conference of ophthalmologists was held in the Middle East and among the subjects that of calls of war on eyesight was discussed. High-grade vision was needed in mechanised warfare; clear sight in the right eye was often essential; good binocular vision was desirable too. In this climate eye strain became more significant, but sun glasses were not generally recommended. Eye strain was sometimes found to be due to other causes. For instance, a large number of girls in the A.W.A.S. experienced strain while working in parachute refolding platoons, and an unusual proportion reported for eye testing. Good lighting was essential for this work, and constant work with coloured fabrics accentuated symptoms associated with minor errors of refraction.

Special problems arose with the use of anti-gas respirators. A special frame, mark III, with flat wings was used for correcting the sight of men who could not see without help. The presbyopic were handicapped also. Major Bruce Hamilton described a simple "clip-in" device which was a modification of Kinmont's appliance. By placing the corrective lenses at the inner side of each eye piece and providing a means of adjustment for the pupillary centre, the device was made effective. Fortunately, these problems did not need practical solution on the field.

Ocular muscle balance was not found so important in the army as in the air force, but in the later years of the war when the full use of all available manpower was so essential, asthenopia became more significant. Bruce Hamilton tested the ocular muscle balance of 3,285 men and found 599 (18.2 per cent) showed some degree of imbalance. Most of the equipment used was home-made. He submitted 125 patients to orthoptic treatment, using whole day sessions, and obtained successful results in 79 per cent of these. One half of the convergent insufficiencies seen had a psychological basis. No regular equipment for orthoptic training was available in the army, but in some of the capital cities in Australia treatment was available through the cooperation of the R.A.A.F. at their orthoptic clinics.

Night vision was of military importance also, and is dealt with more in detail in the histories of the R.A.N. and the R.A.A.F. medical services. In the Royal Australian Navy, Dr James Flynn described a simple adaptometer constructed by ships' staffs by which the outline of a movable silhouette was observed in different degrees of illumination, produced through 16 different-sized apertures. In the army no standard test for dark adaptation was adopted, but medical units requiring an apparatus usually constructed one themselves. Bishop Harman's disc spotting test was generally employed. Towards the end of the war the night vision training and testing unit of the Royal Canadian Army Medical Corps

was obtained by Colonel J. H. Anderson, A.D.G.M.S., London and sent to Australia.

During the siege of Tobruk a number of men complained of night blindness, but the history was not accepted at face value, as the trying conditions there led to some exaggeration of symptoms on the part of those carrying out unpopular duties. There was no reason to suspect any vitamin *A* deficiency at the time, as the diet appeared to supply enough. The contrast between the glare by day and the blackout by night certainly imposed a strain, accentuated by any refractive error in men driving motor transport vehicles. No fundal changes were found in these men's eyes.

In Australia, later, tests of night vision were carried out at an army field vehicle school, and some observations were carried out before and after the giving of vitamin *A* in capsules.

In general the commonest cause of a complaint of defective vision at night was psychological, and for that reason it was wise not to draw attention to the subject.

INFECTIONS OF THE EYES

In the Middle East there were some analogies between infections of the skin and those of the eye, as the factors of environmental trauma, due to diet and dust, and bacterial contamination, were to some extent common. Conjunctivitis was sometimes apparently due to non-specific bacterial causes, at least specific organisms were not always isolated. It was not infrequent in men in the desert, owing largely to exposure to sun, wind and dust. Blepharitis was common and was often related to scurf in the scalp. No gonococcal ophthalmia was seen and no trachoma in Australian soldiers. Some of the affections of the lids were troublesome; a mixture of styes and an ulcerative type of blepharitis caused much thickening of the lids and resolution was slow. The infrequency of conjunctival infections in Tobruk in 1941 was remarkable, in view of the prevalence of septic sores on the skin, the dust, the swarms of flies and the shortage of water. Subacute relapsing forms occurred, resembling the Morax-Axenfeld type. Sulphonamide drugs were occasionally helpful. Experiences in the Middle East and in the Pacific Islands showed how important was corneal ulceration. It was doubtful if it was wise to send any man to the tropics who had previously had ulceration of the cornea. At least it was unwise to grade him in class A.

In New Guinea and similar humid climates, much of the palpebral and conjunctival trouble was due to sweat, dirt and dandruff; some was, in the opinion of Major K. B. Armstrong, associated with allergy. The most serious type of conjunctivitis was that due to the haemolytic *Staphylococcus aureus,* coagulase positive. When penicillin was available this was found to be effective, though the risk of contamination of diluted penicillin drops by the *pyocyaneus* organism was found to be real enough to warrant a special instruction describing the necessary precautions. Corneal ulceration was common with infections of this kind and tended to relapse.

In Thailand and Burma outbreaks of corneal ulceration were seen in various areas. At Thanbyuzayat and Tamarkan fulminating ulcers occurred, developing so rapidly that in 48 hours a mild conjunctivitis became a violent chemosis, with pouring discharge and widespread ulceration of the cornea, which sometimes showed bulging. Fortunately the necessary drugs for treatment were to hand on this occasion and with assiduous attention the results were good, though opacities cleared slowly and sometimes persisted.

KERATITIS

Various types of keratitis were seen in the Middle East. Major J. Bruce Hamilton concluded that about two-thirds of these were of the type presumably due to the virus of *herpes simplex*. A previous survey in Tasmania had convinced him of the connection with *herpes,* and of the existence of a number of corneal lesions in addition to superficial punctate keratitis. In the Middle East the same characters were observed; the appearance of the infection after pyrexia due to infection or non-specific protein injection, the tendency to relapse, the absence of conjunctival and uveal reaction, and the varied types of corneal lesion. Superficial punctate keratitis, marginal keratitis and dendritic ulcers were common. During the year ending September 1943 Major John Pockley saw 78 cases, all unilateral and of rather unusual kind. Conjunctival changes preceded the corneal signs, and the predisposing factors were thought to be malaria (in less than half the cases), typhus and malnutrition. The only form of treatment of sure value was daily application of 2 per cent silver nitrate. Results were usually good, but in some of the established infections corneal opacities remained. In New Guinea, Major W. J. L. Duncan found that among the troops infected with malaria there was an increased incidence of keratitis associated with *herpes simplex*.

TRACHOMA

No trachoma was seen in Australian soldiers, except a few who had previously suffered from the disease, but during the latter part of the war an ophthalmic survey of Australian natives was carried out west of Alice Springs. This was done by Chaplain Frank Flynn, who was also an ophthalmologist and acted there in a consultant capacity. As might be expected, the main disease encountered was trachoma; 448 aborigines were examined and only 51 were free of the disease. In older people the cornea became opaque, 7 per cent of the natives examined were blind in one or both eyes; scarring of the lids also caused deformities. Younger people up to 35 years of age showed varying degrees of activity of the trachoma, but at this stage there was no corneal infection. Under local conditions where efficient treatment was often lacking, corneal ulceration occurred and these frequently perforated, causing loss of vision; prevention was of course a matter of cleanliness and training. No simple efficient method of treatment was practicable as local applications, such as copper sulphate, could not be used long enough to do good. Sulphanilamide gave very

encouraging results. Penicillin was useful for corneal ulcers, and secondary infection, but had no effect on the original condition. The close contact of the natives, the continual presence of flies, dust, dryness of the air and glare were pre-disposing conditions.

It is of interest that trachoma among white Australians has declined steadily in the last generation. Even its frequency in Egypt did not cause a hazard to our troops.

EPIDEMIC KERATO-CONJUNCTIVITIS

Reports of a severe type of virus infection of the eyes from the United States of America and elsewhere caused a special instruction to be issued on the subject. Whether similar and earlier outbreaks were due to the same cause or not, was not of great importance, but in 1942 the highly contagious nature of this epidemic disease warranted special care in the services. The features included an incubation period of three days, malaise and fever, enlargement of the pre-auricular gland, acute purulent conjunctivitis of both eyes, with oedema of the lids, and almost invariable development of corneal infiltrates after 6 to 10 days. The corneal opacities were discrete plaques under the epithelium interfering with vision; they resisted all treatment and persisted for weeks or months. The measures advised were isolation and notification, bland irrigation of the conjunctival sac, and analgesic instillation when sensitivity to light was troublesome.

Major J. Hercus described an outbreak of 56 cases among Australian troops in North Queensland. Late in the summer of 1944-1945, an epidemic occurred, fortunately mild by comparison with those recorded elsewhere. Troops of the divisions were affected, the number in the area being from 50,000 to 70,000. Many of these men had malaria but there was no apparent connection. A mucopurulent conjunctival discharge appeared, with thickening and tenderness of the lids, and occasionally ulceration. There was no fever. The pre-auricular glands were swollen in half the patients. Vision was partly lost, and photophobia was common. Treatment with silver nitrate gave good results as a rule, though the deeper lesions took a month to resolve. Cultures revealed no bacteria, nor could a virus be grown. Mononuclear cells were found in the conjunctival exudate, but no inclusion bodies. No epidemiological data of importance could be discovered.

OCULAR COMPLICATIONS OF OTHER DISEASES

Relapsing fever occasionally caused iridocyclitis, so too did bacillary dysentery of the Shiga type, but this complication was extremely rare. In the latter, this rarity was possibly due to the early introduction and adequate use of sulphaguanidine.

Arsenical treatment in relapsing fever did not seem to improve the eyes, but complete recovery took place eventually. Conjunctivitis was an occasional event during the course of dysentery.

Malaria caused few ocular complications. Conjunctivitis was occasionally seen, and dendritic ulcers, as mentioned above; such relation was

probably non-specific. Sometimes in severe malaria hyperaemia of the optic disc was seen, and more rarely tiny retinal haemorrhages. Considering the pathology of malignant malaria, this is not difficult to explain.

Scrub typhus was productive of rare, but more serious eye complications. Thromboses in the central retinal vessels were seen in 7 out of 600 patients with scrub typhus; these varied from blocking of a small branch to complete bilateral thrombosis of the retinal arteries in one instance. Conjunctivitis was also seen, sometimes with subjunctival haemorrhages, and during convalescence paralysis of accommodation was not uncommon, persisting sometimes for months.

INJURIES OF THE EYE

1. *Environmental Trauma*

Dust acted as an irritant, but there were possibly other factors related to the size and physical nature of dust particles and the presence of infection. In the desert the dust was comparatively harmless; in more settled areas possibly this was not so. In view of the frequency and intensity of ocular infections in Palestine and Egypt, it is perhaps remarkable that more infections of soldiers did not occur.

Heat and light certainly played a part in producing conjunctivitis. The chronic infection of the lids often seen in the Middle East was probably due to non-infective factors.

Glare introduced a rather different problem. In Palestine Armstrong and others found that eye discomfort and headache were frequently associated with a refractive error whose correction relieved the symptoms without the aid of tinted glasses. In October 1940 the question was raised of the effect of glare on troops; at that time the reply was that antiglare glasses would be impossible for fighting troops. This proved to be only a partial answer, for, though it was on the whole better for the men to become accustomed to glare, a great deal was asked of their powers of adaptation from blinding sunlight by day to blackout by night. It was pointed out that dark glasses can do psychic harm and reduce powers of adaptation. Yet some men felt keenly the strain of glare on the desert; drivers of motor transport and anti-aircraft gunners for instance were in need of relief. Considerable help was given by the Australian Red Cross Society in providing goggles for drivers, and numbers of men bought Crookes or polaroid or other tinted lenses. Though there are men who exaggerate the effects of glare there are circumstances in which some protection is desirable. In lookouts in the navy and aircrews in the air force, special problems arose which will be dealt with in those histories.

In 1941-1942 in Syria, men at the ski school at the Cedars not infrequently had conjunctivitis, a well-known result of undue exposure to short wave radiations; photophobia from intense reflected light, under such conditions, was sometimes severe. The sclera was very congested, particularly where it was not covered by the lids. Blepharospasm sometimes was troublesome. Major J. M. Dwyer pointed out the similarity of these symp-

toms to those observed in motor transport drivers travelling over the 620 mile road from Alice Springs to Larrimah. In 1943, no less than 1,250 men were needed for this work, and a problem was created when many of them complained of eye strain. Dwyer noticed that less trouble was encountered after rain, and attributed this to the presence of cloud. Symptoms appeared after a latent period of a number of hours, with intense photophobia and congestion of the sclerae. Superficial punctate corneal lesions occasionally appeared. The road was bituminous, and there was no more dust than in many other places. Excessive drying was a possible factor in producing conjunctival hyperaemia. Chaplain Flynn produced evidence of a connection between this condition and the evaporation rate in different seasons, and pointed out the influence of certain individual differences in eye structure and function, such as the width of the palpebral fissure, the prominence of the globe, the frequency of blinking and the rate of tear formation. The eyeshields of respirators were helpful in preventing drying, but not all motor drivers were tolerant of them. Dwyer found that a green strip painted at the top of the windshield gave satisfactory relief, and this was adopted as a standard measure. It is interesting to contrast this with the complaints of glare by numbers of patients engaged in general duties, reporting at the 107th A.G.H. at Berrimah, near Darwin, at the end of 1945. Practically all of them had no defect of vision, but they complained also of general fatigue. No treatment was found necessary other than reassurance that they would lose their symptoms when they went south; there was no doubt a considerable psychological factor present.

Pterygium.—During the first summer experienced by troops in Palestine, numbers of men reported complaining of *pterygium*. A striking feature was the abundance of the growth on the conjunctiva, and its activity, which was greater than that seen in Australia. During 8 or 9 months some of these increased considerably in extent and bulk. Operation was followed by a definite reaction, and even simple marsupialisation produced local irritation for some time. It was found better to defer operation till the cooler months. In fact, the suggestion was made by an ophthalmic surgeon that if a *pterygium* of size warranting operation was present in a recruit, operation should be performed in Australia. The exciting causes in the environment were probably a combination of heat, glare, dust and drying effects. After the forces left the Middle East, *pterygium* receded in importance.

2. *Photoretinitis*

This potentially serious thermal lesion of the retina, due to infra-red rays, was of particular importance in anti-aircraft personnel. It is of interest to all Services, and effective preventive measures are not difficult. A description of the clinical and experimental work done on this subject will be found in the medical history of the Royal Australian Navy. One important feature may be mentioned here which was emphasised in these observations, that protection afforded by cutting down the visible radiations reaching the eye may give an illusory degree of protection. In civil life even recurrent warnings do not prevent people from exposing their

eyes to the hazard during eclipses of the sun. Three men were seen in Changi on Singapore Island in 1944 by Major R. Graeme Orr suffering from eclipse blindness.

3. *Damage due to Toxic Gases*

Special instructions were issued to all Services concerning anti-gas measures, and first aid procedures should contamination occur. The treatment for mustard gas and similar irritant gases included methods advised for the eyes. Irrigation was not advised except in the earliest stages if droplet contamination had occured a few minutes previously. Full pupillary dilatation was advised. Fortunately these instructions were never required in practice.

4. *Eye Wounds*

In some features the eye injuries seen in the Middle East differed from civilian injuries. Sometimes patients with eye injuries did not arrive at a general hospital before a week or more had elapsed. In one hospital 55 soldiers were seen with a perforating injury of one or both eyes. Of these 33 came from Tobruk, where the conditions were of particular interest owing to uncertainties and difficulties of transfer of wounded men to base areas. Non-penetrating wounds were common there and were associated with the embedding of a lot of dirt. Major Morlet, the ophthalmologist with the 2/4th A.G.H., had always to consider what time would elapse before the man would again be in the hands of a surgeon. In Tobruk one eye had to be removed in 18 instances, and in one, both eyes. In the base areas a number of injuries were due to accidents, some of military type, others not. Foreign bodies in eyes raised problems. Many of them could not be dealt with by a giant magnet because they consisted of non-magnetic alloys. Others were not radio-opaque, being tiny particles of stone or sand, and multiple foreign bodies were common. Fortunately, sympathetic ophthalmia was not seen. A giant magnet was considered an important part of a hospital's equipment despite its limited sphere of usefulness, as some eyes could undoubtedly be saved by its use. A modern and practical giant magnet was specially designed in Australia, and manufactured in Melbourne. During the latter part of the war a magnet was available at strategic points in Australia and New Guinea. Sweet's localisers were also available at ten general hospitals and at base hospitals in most capital cities. Special instructions were issued dealing with the care of eye sockets after excision whether due to wounds or other reasons. The important points were the appropriate dealing with infection, provision of a temporary prosthesis, and, where retentive appliances or repair of a socket were also necessary, sending the patient to a plastic surgical unit.

Artificial eyes were made in the field by dental units, acrylic resin being used, and high degrees of excellence in fit and cosmetic effect were attained. Where this could not be done temporary prostheses were made of vulcanite in a dental laboratory.

GENERAL SURGERY OF THE EYE

The final technical instruction (No. 130) on ophthalmology issued in 1945, summed up the surgical practice of the eyes in army hospitals. *Pterygium* was operated on only when advanced. Operations for strabismus were not undertaken except for reasons considered specially cogent by the surgeon. During the war cataracts had to be considered, as some matured. If the soldier was incapable of resuming his re-enlistment occupation, or of following some other occupation, or of undergoing special training for a skilled calling, operation for the senile type of cataract was performed, but only in base hospitals. Glaucoma was also treated surgically in base hospitals or in the field, if acute in type. Retinal detachment usually required treatment in a base area. Some instances of this condition were reported by Major C. Colvin. Diathermy of the sclera over the affected points with aspiration of sub-retinal fluid below was used with satisfactory results. Corneal transplantation was carried out in one instance, by Peter B. English and J. McBride White, on a Sepik River native warrant officer, in 1945. This man had serious corneal scarring following accidental burning by a phosphorus bomb, and after transplantation of the cornea from the eye of a fatally injured soldier, sufficient vision was restored to enable the man to make his own way about.

BLINDNESS

Loss of vision in one eye or loss of one eye at first did not specifically exclude service with the A.I.F. A soldier who lost the sight of one eye through battle casualty or accident was classified C2 or D in the Middle East, but if he had 6/6 vision in his remaining eye and wished to remain with the force, a note was made on the board papers by the medical board. Later the definite ruling was that loss of sight in one eye would preclude a man from oversea service.

In November 1943 organisation began to collect information about service members in military hospitals who were thought likely to lose their sight, so that early training and re-education could be begun. By February 1944 a War Blinded Welfare Committee had been formed, with the object of correcting errors of environment and mental state in affected men and to give them an interest in re-education as soon as possible. The psychological aspects of loss of vision have been clearly recognised for a long time, and the excellent examples of training in special institutions have had a most inspiriting result during the last generation. The early "flattening" of emotional reactions are often illusory and may be followed by depressive states or conditions of great tension. Writers like Harrowes have estimated the proportion of war-blinded men who have developed a characteristic tensive depressive state at rather more than one-third. Restabilisation can usually be attained, however, and emotional balance is achieved. The psychological reactions of men who have lost one eye often need consideration also. These changes may be out of proportion to

the seriousness of the loss, and need careful handling lest a resistant attitude develop.

During 1939 to 1945, 2,423 men were discharged from the Australian Military Forces by reason of diseases of the eyes, and during 1946-1947 another 122. Of these, the total numbers discharged for loss of, or blindness in, one or both eyes, was as follows—

Loss of vision in one eye - 203
Loss of vision in both eyes - 16

It was of importance to define blindness for the purposes of restoring men to occupation, and on the 11th February 1946, a conference was held of representatives of the army, the Repatriation Commission and Associations and Institutions for the Blind. For the purposes of rehabilitation the definition of blindness was agreed to be inability to fill an occupation requiring sight. It was recognised that men who could move about freely with good peripheral vision would be seriously handicapped by loss of central vision. It was agreed also that it would be to the soldier's financial benefit to come under the care of the Repatriation Department soon, and the timing of his discharge therefore needed consideration. Arrangements were made for training centres to be established in several states. Special problems arose with men suffering from nutritional amblyopia, whose final medical boarding would be better deferred till their condition was approaching stabilisation. Further aspects of the training and care of men with varying degrees of loss of vision are outside the scope of this narrative. The importance of the problem is, however, great; early in 1946 an estimate was made that some 600 soldiers would come within the official definition of blindness (which as pointed out above, does not mean total loss of sight), and that at least one-quarter of them would need special training.

AMBLYOPIA

Impairment of vision from non-traumatic causes would not have been of serious magnitude as a war disability had it not been for the occurrence of large numbers of cases of amblyopia due to malnutrition. The types seen in civilian practice occurred, but were not significant. Quinine amblyopia was of negligible importance. Rare instances of transient affection of vision following high dosage of quinine were encountered, but the careful control of this drug and its administration prevented trouble.

For over a generation the occurrence of nutritional amblyopia has been known and the literature contains numbers of references. It is of interest that Sir James Barrett pointed out during the 1914-1918 war that visual disturbances occurred in Turkish prisoners of war, which were ascribed by him to pellagra. Most of these described a so-called retrobulbar neuritis followed in some instances by partial and largely selective optic atrophy. The majority, but not all, were observed in native races in the tropics. Nevertheless, the menace of this aspect of malnutrition was only clearly realised when prisoners of war subjected to poor dietary standards were released with severely damaged sight. The question of cause was reopened

and vigorously discussed. The possibility of a toxic cause was debated, but it seems likely that it is purely a result of deficiency, which may not be alone due to the lack of riboflavin, and whose mechanism may be due to toxic symptoms arising from withdrawal of substances necessary for specific cell metabolism.

Unfortunately there were ample opportunities of studying this nutritional amblyopia among the prisoners of the Japanese in South-East Asia. The results of these studies will be found more fully treated in the section on malnutrition.

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CHAPTER 58

PATHOLOGY

THERE is in one sense little to write about clinical pathology *per se* in relation to everyday medical and surgical work during war, because it is inextricably woven into the fabric of modern medical practice. It is true that it is not always possible to have the pathologist available in forward areas, but his influence still pervades the work done there. The highest development of pathological and biochemical services was naturally in the army, with its large ramifications of land forces. From the beginning of training in the Middle East, fully equipped pathological departments were part of the establishment of hospitals, and mobile bacteriological laboratories also provided full services. Difficulties in supplies were for a time considerable, including a scarcity of guinea pigs in Palestine. Valuable experience was obtained there in tropical diseases, and when the scene shifted to the Pacific Islands, this branch of work became a major issue. Indeed when malaria became a daily or rather nightly hazard in the islands, and its diagnosis from dengue and other febrile diseases was necessary, medical officers in forward units, particularly field ambulances, underwent a special brief course in the microscopic recognition of the malarial parasite. This need was also felt in the navy and air force, and officers in these services were able to carry out the essential diagnostic work: in addition there were facilities for routine investigation in base units. Field's stain was adopted and its use became the standard method for detecting malarial parasites in thick blood films; it was supplied in diagnostic panniers for forward use. Giemsa and Leishman's stains and their solvent, methyl alcohol, were scarce, and were used with due economy only for special verification of types of parasites when thin films were necessary for this purpose.

The morbid anatomy of disease was closely studied in the field. Even where facilities for post-mortem examinations were not adequate, these were always carried out if in any way possible. Histological examinations of tissues were also made, and the material thus obtained was, in appropriate instances, sent to the base for further expert opinion. The importance of this work was great, and a high standard was maintained. Hospitals even in semi-forward areas often carried out tissue studies of definite value. In order that legal complications might not hamper medical officers in performing autopsies a special regulation, No. 37 of the *National Security Act,* was gazetted giving a qualified commissioned medical officer of the armed forces power to perform a post-mortem examination on request by a coroner of any state or territory, and to sign any necessary certificate of death.

The actual work carried out in the field in pathology and biochemistry may be divided into several categories as follows:

1. In forward units, ships and other isolated installations essential pathological services could be performed with simple material, stains and a microscope.
2. In field ambulances a special diagnostic pannier was provided to enable the differential diagnosis of dysentery and malaria to be made. As these units frequently had to hold considerable numbers of men this was an important function. The work was greatly helped by the attachment of a sergeant technician to each field ambulance.
3. Mobile bacteriological laboratories were provided which used specially designed trailers fitted as a laboratory on wheels. Not a few growing pains disturbed the early days of these trailers, which had to be structurally sound as well as scientifically compact. They survived such indignities as being bogged in training camps in Australia, and being thought doubtfully roadworthy and not always waterproof. They were in fact of very high value and brought pathological services to units such as casualty clearing stations working as hospitals. In the islands the position was different, as mobility there was largely a matter of thinking in terms of air transport, roads being few and impracticable. Mobile laboratories were very useful for special investigations in Australia on occasion. A mobile pathological laboratory was designed by members of the R.A.A.F., so contrived that the equipment necessary for all ordinary work fitted into boxes for ease of transport.
4. Pathological and biochemical services were provided for general hospitals on an adequate scale. The whole range of work was covered and by consultation between physician or surgeon and pathologist most problems could be answered. The amount of routine work was often so great that less important tests were rationed; even in civilian practice the clinician who asks for a test does not always realise the amount of work necessary for its performance.
5. Pathological work was carried out in civil hospitals for the Services, in Government laboratories, in University departments and research institutes. The ultimate solution of some important problems was effected in this way. Unusual demands which could not be met by service installations, particularly at the beginning of the war, were met by voluntary help by these departments.
6. Research was carried out in civilian research institutes throughout Australia practically continuously during the war, and, as occasion offered, by service pathologists also. At the special medical research unit established by the Australian Army at Cairns work of a high order was carried out on malaria. The pathological work necessary in this research demanded great experience and technical skill, in fact the basis of the work was entomological, pathological and biochemical.

Help was given by the National Health and Medical Research Council in planning and subsidising wartime medical research, and much valuable work was also carried out by the Council for Scientific and Industrial

Research (now the Commonwealth Scientific and Industrial Research Organisation). The School of Public Health and Tropical Medicine within the Sydney University rendered almost full-time war service in many fields, acting as court of appeal through its experts in difficult questions, and training hundreds of Allied medical officers in tropical medicine. This school, like other schools of pathology, helped also to train pathologists and technicians who were invaluable during the war. One of the reproaches which medical educationalists could have justly levelled at the community in general at the beginning of the war was that so little encouragement had been given to young medical men and women to adopt pathology as a career that the war found the Australian medical profession unable to supply enough pathologists. This need was supplied by the provision of special courses of intensive training by which pathologists could be trained in a few months. There was no delusion that these schools represented a full standard training, but they played their part in enabling keen and able junior officers to be equipped for the needs of hospitals in the field. Experienced laboratory technicians were scarce also, and more were trained, though it takes time to train a good technician.

The great demands of the growing forces required for the defence of Australia and the war in the Pacific made a vast expansion of pathological services necessary. After the return of most of the A.I.F. to Australia this manifold expansion began; it played an important part in achieving an even higher standard of efficiency in all the medical services. In the early war period experienced clinical pathologists engaged in full-time work with the armed forces were few. In fact the first two A.I.F. hospitals in the Middle East had as pathologists specialised research workers, though this probably had an excellent influence on this branch of the medical services in the field. Much of the expansion achieved in the Australian Army Medical Services was made possible by the use of women, even in forward areas, as pathologists and technicians. Details of establishments and administration are dealt with in another volume.

Without the help of the pathologists left to serve the civil community the work in base areas could not have been done. In out-patient departments attached to recruiting centres, in civil hospitals and in research institutes, a remarkable volume of work was carried out, much of it by part-time pathologists. Without the help of civil hospitals and their technical staffs rush jobs like that of performing blood type examinations on the members of the expeditionary force would have been impossible. The accuracy of that work and much other similar work done in the same way is proof of its quality.

Conferences of pathological experts from time to time decided matters of great importance for the services, helping to produce material, to test its efficacy, and to advise on methods such as immunisation designed to prevent disease. The text of this volume abounds in references to prophylactic and therapeutic work whose basis is pathological. The larger military areas coopted the services of University professors of pathology and bac-

teriology as part-time consultants: their help in deciding policy and in carrying out projects was invaluable. Similar help was obtained from members of staffs of chemistry departments, and valuable work was carried out on the synthesis of a number of drugs not previously made in Australia.

The Commonwealth Serum Laboratories at Royal Park, Melbourne, produced a practically complete range of biological products throughout the war, supplying the services and civil community. Important items were material for immunisation against various diseases, antigens and antisera for serological diagnostic work, therapeutic antisera and antitoxins, and notably penicillin. An army technical instruction laid down a schedule of items supplied by the Serum Laboratories which could be obtained on request: others required approval by the D.G.M.S. Dates of expiry of these products were carefully watched. A deadline date of two years was adopted as a general standard in a technical instruction, 10 per cent annual deterioration was otherwise allowed. Fortunately most agents were relatively stable if properly kept. The supply of biological preparations to pathological laboratories was to some extent rationed. This was necessary for two reasons, to conserve scanty and precious materials, and to avoid overloading of civilian staffs.

Certain diagnostic materials were not supplied, such as *Salmonella* agglutinating sera and living cultures. When these were required for identification purposes material was sent for tests at headquarters. Tests were standardised as far as possible: for example, one precipitation test was authorised for syphilis, the Kline test. Culture media were not supplied, as laboratories were expected to prepare their own, but limited quantities of dried media were available for laboratories without full facilities.

Outstanding work was done by the Walter and Eliza Hall Research Institute under Dr F. M. Burnet. Here research was carried out on the incidence of influenza and methods of immunisation, other virus diseases, such as poliomyelitis and psittacosis, rickettsial infections such as Q fever (which was found amongst Allied troops in Italy), scrub typhus and other varieties of typhus fever, anaerobic infections, purification of water, and non-specific urethritis. It was most unfortunate that the typhus research added another brilliant worker, Miss Dora Lush, to the already considerable list of scientists who have lost their lives in this work.

Many instances will be found throughout this volume of the work carried out on the pathology of disease during the war. It covers a wide range including tropical diseases, their diagnosis, epidemiology and pathology, routine and research work on the morphology and chemistry of blood and other body fluids, drug concentrations in body fluids, investigation and control of wound infections, general bacteriological work, parasitology and serology.

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CHAPTER 59

RADIOLOGY

At the outbreak of war, the D.G.M.S. of the Army, having no radiologist on his staff, obtained assistance from a committee of radiologists in Melbourne. This was a standing committee established by the Radiological Section of the Victorian Branch of the British Medical Association to advise about X-ray equipment, particularly for country hospitals. The advice of this committee on the type and quantity of X-ray equipment for use in the armed forces was taken in most such matters after the early part of 1940. Later, assistance was also given by representatives in other centres of the Australian Association of Radiologists. Dr C. E. Eddy, physicist-in-charge of the Commonwealth X-ray and Radium Laboratory, carried out many tests on items of equipment, including apparatus for miniature photo-fluorography when this method was first introduced. At a later date he also made reports on films carried by X-ray workers in army hospitals as a check on exposure to radiation. An "Ultrays" set was selected for general use in each general hospital. Spares were provided for units, including two tubes, pairs of shock-proof cables, screens, Potter-Bucky diaphragms *et cetera.*

MINIATURE RADIOGRAPHY

The introduction of miniature radiography into the Australian Army was of outstanding importance. The events leading up to the dramatic last minute radiological examination of the 16th Brigade of the 6th Division of the Second A.I.F. belong to a pre-war period.

In August 1938 Dr H. W. Wunderly of Adelaide began a survey of young women in Adelaide between the ages of 15 and 30, with the view of detecting pulmonary tuberculosis. Those who gave a positive reaction to the Mantoux test were radiographed on 17″ x 14″ films. The results of this survey were published in 1939. Early in 1939 Dr Wunderly received from Dr W. Pagel, at Papworth in England, information that he had read a report of a mass survey of over 50,000 S.S. troops and over 50,000 members of the Berlin police force. With the use of a 35 mm. film photographs were taken of the image on a fluorescent screen. By April 1939, using primitive apparatus, Dr Wunderly was convinced that by miniature fluorographic methods he could demonstrate on a 35 millimetre film evidence of chest lesions in the subjects of his survey. These findings were confirmed on 15″ x 12″ films. Realising that this method might be of value in the examination of recruits on enlistment or in surveys of the general public, he brought it to the notice of Colonel S. R. Burston, later Major-General and D.G.M.S., who was then D.D.M.S. of the 4th Military District, and on 4th May 1939 also wrote to Dr J. H. L. Cumpston, Director-General of Health. Dr Cumpston sent extracts of this letter to Dr C. E. Eddy and asked him to make a technical report on the method. On

18th July 1939 Drs Eddy, J. O'Sullivan, Eric Cooper and H. Wunderly met in Melbourne to discuss it, and on that day arrived the German journal reporting the German experiences. They decided to recommend that the use of the method in Australia should be further explored. Dr Eddy obtained the necessary equipment, and made a favourable report on 20th September 1939. Not only had the technical aspects been investigated, but clinical trials were also made. Miniature radiographs of chests taken by this method were submitted to the critical scrutiny of several radiologists and physicians. Among the latter was Major Eric Cooper, who was at the time deputy to General Downes, the Director-General of Medical Services of the Army, then on an official tour overseas. In August Cooper sent samples of films to Downes, who found that they were of better technical quality than similar films being then produced experimentally in England. The same opinion was held by the Australian advisers. General Downes, returning hastily from America on the outbreak of war, advised the incorporation of this method in the routine examination of recruits for the special force which became the Second A.I.F., and in November 1939 the Minister approved this recommendation.

Dr Eddy produced specifications on 5th December 1939, a tender was accepted on 14th December, and the equipment was hastily constructed, assembled and approved. The apparatus was despatched by road to Ingleburn, N.S.W., where the 16th Brigade A.I.F. was preparing for departure overseas. Unluckily the truck overturned on the road, damaging both the equipment and some of those in charge of it. With commendable energy the equipment was replaced and repaired in less than a week and finally reached Ingleburn in time for a radiological survey to begin on the last day of 1939. Great credit is due to all who conceived and carried out the work leading to the successful adoption of this valuable method: in particular the drive and initiative of Eric Cooper were largely responsible for its successful establishment as a standard procedure.

When the brigade sailed on 10th January 1940, 6,775 men had been radiologically examined by this method, 33 being rejected on radiological grounds. As many as 220 men per hour were examined and this rate was maintained for 10 hours at a time. Diagnostic teams reported on the films enlarged on a screen and where doubt existed full size films were taken, a standard practice adopted with this method. The method was not without its critics. Some radiologists objected that the accuracy of a 35 millimetre film was not comparable with that of a 17″ x 14″ film. This could hardly be expected and missed the point, for the miniature method was essentially a "screening" procedure, not designed to supplant refined techniques. Extended experience has shown that a miniature film of good technical quality will reveal to a team skilled in this branch of X-ray interpretation doubtful shadows which may or may not be significant and which require further investigation. It is of interest that dissection of the first large series in the R.A.A.F. showed that the accuracy of the miniature films closely paralleled that of the standard size films. A series of 17″ x 14″ films taken of 1,293 men disclosed pathological lesions in 2.5 per cent, while in a

further series of 2,526 men examined by miniature films the percentage was 2.7, an almost identical figure. Thus after a hectic beginning miniature photo-fluorography became recognised as a reliable method, and in the first two months 22,000 men were examined at a total cost of about fourpence per man. An unfortunate difficulty arose because of the insistence of the army authorities that this unit should be capable of operation by a petrol-driven generator. The limited output of these generators caused the adoption of a self-rectified unit delivering 100 milliamperes at 85 kilovolts, whereas most of the camps where they were used had satisfactory electrical supply which could have handled a much more powerful unit. Later, units for base areas were converted to four valve rectification, thus improving the pictures and shortening the time of exposure. The navy and air force and later the munitions health services also installed micro-radiographic equipment. Technical improvements were investigated at the Commonwealth X-ray laboratories, and were incorporated with good effect; in particular the adoption of fixed grids improved the results. The necessity of constant technical control was evident in the whole history of this method.

Mobile X-ray units were later provided for mass surveys, with adequate staff and, preferably, facilities for using self contained generation from a standard 25 K.V.A. generator, as some of the areas visited had no suitable local supply. With these it was found that up to 240 soldiers could be handled per hour for short periods, but over long periods the number fell to 150 or 120. Films could be reported on at a rate of 300 per hour with examiners experienced in the technique, and this number was generally accepted as the highest rate compatible with accuracy.

The army medical services strongly pressed that the men called up under the provisions of the universal service and the members of the militia on full-time duty should be radiologically examined as well as the A.I.F. Wide scattering of some of these away from base areas caused some difficulty, and for a time there was opposition to the full adoption of this method. The question of legal attributability arose in the case of men who had been in camp for some time and who were later found to have pulmonary tuberculosis. It was even suggested that a ruling should be adopted that attributability should not apply if the period after entry into camp was not over two months. Even at the end of 1943 there were 4,000 men in the Northern Territory who had not had an X-ray examination of the chest. In the end the practice became universal: not only members of the armed forces were so examined but also others accepted for special duty, such as the Allied Works Corps and the Women's Land Army. The revolution caused by the introduction of this method in the encouragement of mass surveys has so changed the outlook of both medical and lay communities that it is now hard to realise that in 1939, X-ray examination of the chest was not part of the standard examination even of permanent soldiers.

RADIOLOGICAL WORK OVERSEAS

Many difficulties were met in the early days, owing to necessary extemporisations, stringency of supplies and other local troubles. One improvement could have been made had all radiologists appointed for overseas service been given opportunity to become familiar with the apparatus they were to use, and to check the whole of their equipment personally. Packing difficulties also arose at first, some of the packages being too heavy for careful handling, and delicate items like tubes were not under personal care of a responsible person, with the result that frequent breakages occurred of these vital parts, imported from abroad. Many tubes of the standard X-ray unit were thus lost, being not oil-immersed and rather vulnerable.

Variation in local electric supply caused trouble in Palestine and elsewhere and was a constant source of worry until a mobile standard 25 K.V.A. generator was supplied widely throughout Australia and the South-West Pacific Area. Scarcity of spare parts was relieved to a good extent through the work of the Medical Equipment Control Committee in Australia. When the 6th and 7th Divisions left the Middle East to return to Australia, all radiological spares were taken with them, including by mischance a part sent to the Base Depot Medical Stores for repair. This caused for a time some stringency in spare parts needed by the 9th Division. Some of the equipment was rather fragile like developing tanks, which were at first made of a compressed composition, later replaced by stainless steel. Such breakable articles met a fate similar to that of other packages subjected to manhandling in and out of ships.

The standard X-ray unit gave good service. Though not as powerful or flexible as units familiar to civilian radiologists, it filled its role of a field unit. Exposures for some types of work were rather long for critical work, but this was to be expected. The equipment of the 2/4th A.G.H. proved its durability, for it withstood shipwreck and exposure to sea, sand and sun, and later served well in Tobruk.

Deterioration of film was troublesome in the tropics. The Australian "tropical pack" film supplied by Kodak stood up to the conditions well, but film imported from Europe in non-tropical packing did not. Lawler's method of restoring fogged film was found useful. It was made a standard method in December 1941, so that reconditioning could be carried out in any hospital unit. Fogged film could be restored successfully, though a loss of 20 per cent in speed was observed.

Towards the end of the war, a world shortage of film enforced strict economy and attempts were made to reduce film expenditure by 50 per cent. Proper storage of film was not always possible. In hospitals facilities for storage in a cool place were invaluable: during some periods of stress requirements could not have been met had local supply through British forces not been largely supplemented by stores brought originally with the units from Australia. Full examination of the chest could not always be made easily, as 17″ x 14″ films were not used by British units in the Middle East, and Australian radiologists wishing to use this size had

to fall back on supplies they had brought with them. In Singapore medical units of the 8th Division A.I.F. had no facilities for storage of X-ray films: this was about to be provided when action began. In other places in the tropics similar conditions existed, and deterioration of the emulsions was inevitable.

Trouble was encountered in the developing and drying of films in hot climates. If ice or a refrigerator was obtainable development could be controlled, but films still suffered during drying at high temperatures. Accordingly full details of the high temperature developments method such as used in the Connaught Military Hospital in Poona were circulated as a technical instruction in the Middle East. This method, in which sodium sulphate was employed, was used extensively: it secured freedom from frilling, irregular or "grainy" texture and abrasion marks. The process made ice unnecessary. At Labuan difficulties with developing were overcome by collecting water early in the morning and passing it through an ice coil into the storage tanks. Water so treated could be stored at 70°F., which otherwise would have attained a temperature of 90°F. by noon. Shock-proof cables had a limited life under tropical conditions; some radiologists thought this did not exceed six months. Lack of scrupulous care in avoiding kinking and rough handling might have shortened this period, but there was no doubt that deterioration occurred in tropical climates.

Climatic conditions were also responsible for the growth of a fungus on X-ray apparatus. In the humid heat of the Pacific Islands tubes which were not of the oil-immersed type were affected and fungus also grew on the intensifying screens. Accommodation was often rather cramped, particularly when departments were housed in buildings not suitable for the purpose. When the first elements of the A.I.F. reached Palestine, until a properly designed department was built into a theatre block much extemporisation was necessary, and screening could only be done at night. Such experiences were repeated in many medical units during the succeeding years. Casualty clearing stations, in particular, had to use a good deal of ingenuity, especially in contriving a dark room in a tent. Even where good accommodation was provided in a building, much depended on the radiologist and his technician making the most of the space available. Portable dark rooms proved useful, and saved valuable time in setting up. Great help was given by the Radiological Advisory Committee in Australia, especially in the design and lay out of departments, and of portable accommodation. Ventilation was a really difficult problem. Blacking out the room for screening could create conditions in the tropics in which work could be carried out only for short periods, and extemporised dark rooms had similar disabilities. In base areas, of course, in permanent hospitals high grade installations of the civilian type were provided. The range of work done covered the whole field of general radiography, together with such special examinations as urography, cholecystography, bronchography and encephalography. Localisation of foreign bodies was an important branch of work, and where a surgical team had radiological

facilities it was much in demand. The standard equipment supplied for this purpose was accurate and speedy. A frame carrying a grease pencil was used to mark the shadow of the foreign body on the skin in two planes at right angles. The cross wire system was also used with success. Sweet's localiser for foreign bodies in the orbit of the eye was used, though even distribution of the equipment over areas where it was needed was not always achieved. A high standard of radiological diagnosis was maintained, though it was perforce sometimes lowered from the ideal by the inherent limitations of the diagnostic material to hand, and of apparatus designed for field use.

X-RAY EXAMINATION ON DEMOBILISATION

When demobilisation was planned at the end of the war special radiological arrangements were needed. Following the advice of the medical services in the army, navy and air force, Cabinet approved that all service men and women should have a routine X-ray examination before discharge. Civilian radiologists were called in to help with the large number of films which had to be seen and assessed. At the end of the war therefore it was established as axiomatic that no man or woman would be accepted for war service without preliminary radiological examination of the chest, nor discharged on conclusion of service without re-examination.

STAFF

Staff did not present difficulties at first, though the naturally spartan medical establishments of active service imposed considerable strain on the trained personnel. A radiologist with rank of major and a staff sergeant technician did all the radiology for a 600 bed hospital, which often in times of stress greatly exceeded this number of beds. An extra technician was allotted to a 1,200 bed hospital. A radiologist was attached to each casualty clearing station at first, but in the Middle East campaigns it was proved that a staff sergeant technician could do all that was needed technically, the surgical staff assuming the responsibility of interpretation. In 1942 radiologists were withdrawn from casualty clearing stations. This effected a welcome economy in specialist radiologists, but in the great expansion of the forces during the campaigns against the Japanese, shortages of staff became pressing. Accordingly, X-ray schools for radiologists and technicians were established in 1943 under a full-time chief instructor, and were held in Sydney. Lectures were given in physics, anatomy, physiology, electrotechnology, dark room procedure, positioning and diagnosis. These schools were intensive and courses were completed in three months. Successful students were then posted to base hospitals for further instruction and experience. Most of the medical officers trained continued in the practice of this specialty, and later obtained a Diploma in Diagnostic Radiology.

In the Middle East an adviser in radiology was appointed, Lieut-Colonel H. C. Nott, but in 1943 an adviser was attached to the medical headquarters in Melbourne. Lieut-Colonel Colwell was detached from a medical

unit, and was thus free to coordinate the work of radiology in the army and to examine its special problems. This adviser, like the adviser in ophthalmology, filled a very useful function in a technical field.

RADIATION RISKS

In field work, especially with limited staffs, exposure to radiation was important and its effects were closely watched. Some complaints were investigated in the Commonwealth X-ray and Radium Laboratory but they were usually ill founded. Radiation blamed on apparatus was at least on one occasion found to be arising from the patient. The usual periodic blood examinations were carried out on workers in radiological departments. A special technical instruction, No. 63, drew attention to these risks, and directed that all persons regularly working in X-ray departments should wear a Kodak dental A or AD film in the breast pocket with the film side out during the first week of each month. Exposed film marked with the name and unit of the wearer was sent with an unexposed film from the same box to the X-ray laboratory in Melbourne where Dr Eddy reported on them to the D.G.M.S. and the unit concerned. Blood examinations including red and white cell counts and estimations of haemoglobin were made on each X-ray worker at three-monthly intervals, preferably at the same time of day. That these precautions were not unnecessary was demonstrated occasionally. For example a radiologist and his technician of one hospital, in 1942, after a heavy period of work had to be sent off duty for a month, at the end of which time blood examinations gave normal findings. Radiologists of hospitals in the field found that it was essential to ration the amount of screening they did, as this devolved on one person only, and lack of precaution would mean greater loss of time and manpower quite part from any question of risk.

X-RAY THERAPY

Superficial therapy was used in Darwin in 1941 and was later introduced into army hospitals doing a great volume of dermatological work in the Pacific Islands. The type of equipment required was selected on dermatological advice, and specifications were prepared by Dr Eddy. Special care was taken to secure constant measurement of dosage for conditions met in tropical climates. The simplest technical arrangement was for the dermatologist to be responsible for the running of a 140 K.V. superficial therapy machine. Considerable time was saved in hospitals by the provision of this equipment. Deep therapy, occasionally needed in base hospitals, where practically the entire range of civilian medical and surgical work was covered, was more economically applied by making arrangements for the treatment to be carried out in civil hospitals.

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CHAPTER 60

PSYCHIATRY

"It is a disease of the soul which I am to treat, and as much appertaining to a Divine as to a Physician" (Burton, *Anatomy of Melancholy*)

THE future may show that a fuller and juster comprehension of the "mind-body" entity in states of disease began during the war of 1939-1945. War seldom initiates change, but vastly accelerates it, as was shown by the powerful forward movement of technical medicine since the war of 1914-1918. The medical world is still being borne on by its impetus. Surgeons show even greater resource and dexterity, physicians more deeply explore disordered function and seek to restore it with yet more dangerous remedies; the chemist improves on nature's molecular workshop, and the obstetrician and paediatrist influence the make-up of the generation which is to inherit these advantages. Psychiatry has for some time been warning us that there are fallacies even in measurement, and that the technical bias of medicine has been responsible for the neglect of certain factors which are rejected because they appear as imponderables. Psychiatrists, besides being few in number, have to contend with three criticisms of their claim for adequate recognition. In Australia there has been some mistrust of psychiatry because its basis was largely empirical, because of a fear that its influence might dangerously affect manpower during war, and because its work was still confused by archaic notions of the madhouse. Just as the surgeon has been pilloried as the man with a knife, and the physician as a man of inaction, so the psychiatrist has been thought to be merely a doctor of the insane.

During the 1914-1918 war there was a hard fight to gain recognition for scientific medicine, particularly for medical research in time of war. During the 1939-1945 war there has been a struggle against that "organic bias" of which psychiatrists and all thoughtful physicians complain.

A. Graham Butler, in the *Official History of the Australian Army Medical Services, 1914-1918,* gave an admirable account of the earlier history of the study of disorders of the mind. He pointed out how the nature of fear and anxiety and of psychic conflict were clearly recognised, but even the most influential psychiatric teaching of the day was unable to prevent undue emphasis on the material factors. From this imperfect understanding came such unfortunate names as "shell-shock" and "disordered action of the heart". Not only did the lay public seize on the seemingly obvious connection between certain violent manifestations of war and "neurotic" symptoms, but doctors as a body did not favour a psychogenic explanation of many disturbances which suggested strongly to them at least a predominant corporeal component. During the inter-war period even sound teachers would deplore the use of the word "neurotic" as something to be passed over lightly, and pointed out how important it

was to try to discover an organic cause. Experience and wisdom with deeper insight solved many of these problems, but more by knowledge of life than by knowledge of medicine. "Investigation" in the medical sense has meant chiefly radiological, biochemical and other similar special enquiries: inclusion of psychiatric methods, particularly those which explored the deeper psychic levels, has not been much favoured in Australia.

At the outbreak of war psychiatric clinics were gaining in strength and value, but trained workers were few. The magnitude of the mental problems raised by war was realised with some clarity by all interested in military medicine. There was, however, a feeling that the problem was rather one of disposal and accommodation than of method, and that experienced general physicians could handle the psychoneuroses in hospitals, while the lessons of the last war could be applied by the junior medical officers in forward areas with some help and instruction. Nevertheless Brigadier G. W. B. James, Consulting Psychiatrist to British troops in the Middle East, even admitting the recent interest taken by the medical profession in psychosomatic disease, has stated that "the doctors of the Empire, no matter where they were trained, were, with few exceptions, bewildered by the psychiatric casualty; they looked upon him with distaste, and were quite unable to deal with him effectively". To this hard saying with its firm core of truth, might be added the remark that they often did not recognise him when they saw him in his early stages.

In this young medical graduates were not to blame, it was their education which was lacking, for with instruction and opportunity they showed aptitude for dealing with such problems as those of acute exhaustion and fear state. At the other end of the scale the Repatriation Department during the inter-war period had faced increasing difficulties with psychosomatic and psychoneurotic maladies. This was largely due to the prevailing attitude to these conditions, which in itself was intensified by a pension system based on a non-medical point of view.

In 1939 the practical applications of scientific advances in medicine lagged, as they always must, behind the science itself, and this disparity was considerable in the knowledge of mental diseases. In this mental environment grew up the concept of "war neuroses", a term which, unhappily today, still carries a suggestion, even a belief, that damage through the violence of war is alone responsible for the mental disorders of servicemen and servicewomen.

IN THE MIDDLE EAST

Let us trace first the evolution of psychiatric services in the Australian armed forces, and the nature of the problems to be solved. When the 16th Brigade of the 6th Division left Australia in January 1940, a small nucleus of a larger force detached itself from a steadily growing number of volunteers at home, and became self-contained overseas. It was not hard to forecast that this contingent would contain many keen soldiers in the making, but also a not negligible percentage of misfits. Recruiting

had been done hurriedly, examinations were carried out under extemporised conditions, and among those who "leapt to arms" there were those who were over-bold, over-age, or otherwise unable to maintain physical and mental health under conditions which restrict individuality and independence. Within a few months there were numbers of men awaiting repatriation; of these at least one-third were suffering from an illness mainly psychogenic. Review of the first batch of men (some 325) returned to Australia on the first trip by hospital ship showed similar findings.

The types of mental illness seen in the Middle East in 1940 were purely of civilian pattern. There were few psychotics, only 12 out of 325 repatriated in the first batch, and 8 epileptics. The psychoneurotics ranged from men with the severe forms of depressive states admitted to hospital to those with the lesser anxiety neuroses and the psychosomatic groups, including asthma and peptic ulcer. Headaches and "blackouts" were common symptoms, but it was early evident that the most frequent somatic fixation in the army was digestive. Surgeon-Commander H. W. Gault, R.A.N., has, however, pointed out that headaches were a predominant symptom in neuroses and anxiety states in the navy. The correction of small refractive errors was not found beneficial. Major N. V. Youngman has suggested that questioning about any previous eye trouble is a useful adjunct to the examination of recruits. Where the appropriate stimuli were operative, cardio-vascular fixations were occasionally seen, but the "effort syndrome" was not common. The frequency of functional dyspepsia did not surprise physicians at all: familiar civilian types, such as the men who could not eat this and that, appeared at consultation clinics and sick parades. The large numbers of men with demonstrable peptic ulcers were noteworthy, 13 per cent of the first batch sent home. In the early days delays and difficulties in having investigations carried out increased the often obvious tension in these patients, and the long wait for a hospital ship made this component of their illness still more obvious.

Psychoneurotic patients were better to be admixed in the general wards, but even at this early stage it was evident that to group patients in the same wards because they complained of similar symptoms, had many objections. Treatment of psychoses was difficult, as only tents were available, and even with the help of several trained male mental nurses the handling of acutely confused or manic patients was trying to all concerned.

Meanwhile, in May 1940, the question of military psychiatry was discussed in Australia. A conference was convened by the D.G.M.S., Major-General Downes, to consider "war neuroses": representatives of the army, the Repatriation Commission and The Royal Australasian College of Physicians discussed a memorandum on prevention and treatment of psychiatric disorders. This body recommended that the term "shell-shock" should be forbidden, and that the name "anxiety state" should be used in forward areas. The influence of the last war can be seen in this latter recommendation which would have perpetuated a confusion of acute fear or exhaustion states with the ordinary civilian types of neuroses. The usual terminology was recommended for these latter. This conference recognised

a pressing need for instruction of the public and the medical profession concerning the nature of nervous disorders, and advised that acute nervous casualties should be treated as far forward as possible, particularly by regimental medical officers, and also by mobile groups of experienced physicians and psychiatric specialists. Emphasis was laid on prompt disposal and on plans for treating intractable neuroses in repatriated men. One interesting recommendation of this conference was the need of a psychiatric specialist for each division.

Shortly after this, in July 1940, Brigadier Burston, D.D.M.S. I Australian Corps, convened a meeting of physicians in Palestine to discuss psychiatric problems. This body, which included a psychiatrist, advised chiefly on the recognition and disposal of the acute psychiatric casualties expected under action conditions, but also dealt with the methods of handling psychoses and neuroses. Neuroses were classified as mild, moderate or severe. Patients with the mild type, having no gross psychological lesion, might be expected to recover in one month, and were best treated in a convalescent depot and returned to their unit. Those in the moderate class had a reasonable prospect of recovery within two months, and needed hospital treatment before transfer to a convalescent depot. The accepted disposal of this group was by reclassifying by a medical board as class "C" (temporarily unfit) and returning to Australia. The severely affected were to be regarded as unfit, and required hospital treatment while waiting return.

This physicians' committee suggested that the term "exhaustion" be used for acute neurotic casualties arising in action, and that all other terms suggesting bodily or mental damage should be avoided. For other grades of psychoneurosis the usual terms could be employed, such as anxiety state, psychoneurosis, or conversion hysteria. The recommendations of this body were used as a basis of current psychiatric practice in Palestine.

At this time members of the staff of the 2/2nd Australian General Hospital, whose own hospital site was not as yet ready, took over the mental ward of the 2/1st A.G.H., and in a separate area in appropriate building treated the psychotics and severe psychoneurotics. The civil practice was followed of not admitting patients to a psychotic ward unless they were thought to be certifiable. Some months later Colonel G. W. B. James reported on Australian psychiatric patients in the 2/1st and the 2/2nd A.G.Hs. Jointly with the senior physicians of these hospitals, he recommended that a centre be established for the treatment of Australian patients with psychoneuroses, particularly those with somatic fixations, and that this should be preferably at a convalescent depot where occupational treatment could be undertaken. "Effort syndrome" was instanced as one of these types, but at that time only small numbers had occurred, and the experience of the 2/1st A.G.H. led the medical staff to recommend that this name be abolished altogether. Later Brigadier Burston suggested that the name "temporary neurovascular debility" should be used, but little need arose there for a diagnostic label at all, as few men with neuroses then showed vascular symptoms.

At this time huts were being built at Gaza for a semi-permanent hospital, and it was with considerable difficulty that the non-medical hospital designers were restrained from building an enclosed compound for all psychiatric patients. It was evident that psychiatry was still suffering from the stigma of the "asylum".

At the end of 1940 the commonest psychiatric disturbances in the Australian forces in the Middle East was of the psychosomatic type. The proportions of others corresponded closely with those already described on the first homeward trip of the hospital ship *Manunda*. The existing problems were summarised in a special report from the officer-in-charge of the medical division of the 2/1st A.G.H. in January 1941. By this time the first North African campaign had begun and the 6th Australian Division was committed to action in the Western Desert. Anxiety states were of the civilian pattern. Somatic fixations produced such states as asthma, shortness of breath associated with nasal conditions, digestive disturbances including peptic ulcer, post-traumatic headache, rheumatic disorders such as lumbar "fibrositis" and minor joint affections with muscle spasm. A very common complaint of the nature of an hysterical conversion was that of "blackouts", one of the popular terms of the day. Arising possibly from the familiar disability of airmen under great centrifugal strain in aircraft, and no doubt copied consciously or unconsciously from one man to another, this term was often used by men who had no clear idea of what they meant by it.

Prompt recognition of the various factors concerned and treatment were essential with these men. Mixed with these were a certain number of misfits and delinquents. The need for a trained full-time psychiatrist was felt. The situation was summed up as follows. "The staff of the hospital has had in the past the opportunity of gauging the standard of health of the Australian forces so far sent to this country, and in the light of their experience the importance of psychological disorders in the A.I.F. is emphasised even at a time when only a small proportion of troops have encountered conditions of active service in a war zone. The future importance of such disorders is likely to be very much greater."

At the time that this report was made the services of Colonel J. K. Adey, commanding the 2/1st A.G.H., were available for psychiatric consultation, and were of the greatest value, but there was no full-time working psychiatrist.

Meanwhile the position had eased somewhat with regard to the disposal of psychotics and severe psychoneurotics in the Middle East. Accommodation was extended in hospitals and the convalescent depot, and a regular line of evacuation to Australia was now open. It may be remarked that the frequency of digestive disease, with or without demonstrable ulcer of the stomach or duodenum, was not related to any special local conditions, for the Middle East experience paralleled that in other parts of the world. Indeed, pre-war civilian experience might have enabled physicians to forecast the predominance of these disorders, though the proportion of radio-

logically demonstrable ulcers was apparently higher in military than in civilian clinics.

From the beginning of winter 1940 till the end of summer 1941 several campaigns tested the stability of the as yet untried Australian troops. Conditions differed in all these. The swift victorious advance to Benghazi, with its two well-prepared assaults on Bardia and Tobruk, gave the 6th Division experience that helped them in the brief frustrate action in Greece, where a difficult active withdrawal was a challenge to morale. The one-sided air fighting of Greece helped the men to withstand the moral shock of the impossible odds of Crete. The withdrawal from Benghazi imposed a strain on the 9th Division, thus grimly completing its training. In Tobruk an important active role in defence awaited these men exposed to air attack to which virtually no reply was possible. In Syria the 7th Division was tested in a brief campaign in which there were trying episodes of hard fighting and setbacks in difficult country. Here too malaria was for the first time an enemy to be considered seriously.

IN THE WESTERN DESERT 1941

Fear and exhaustion states were seen in the 6th Division in the first desert campaign, but the brief and not formidable resistance of the Italians was perhaps less responsible for temporary breakdowns than the nightmarish isolation of a force for the first time dispersed in those sandy wastes. The men of the 9th Division, however, arriving in Tobruk after a perilous retirement were at once committed to hard tasks in an area which was isolated except by sea. Here only an important degree of incapacitation would lead a casualty on the way to a safe base, and that way was difficult and dangerous. The ability of the defenders to reply to air action was limited; it dwindled and disappeared. Few places were safe unless underground. The active tactics adopted were much better for morale than passive defence, but psychogenic exhaustion and anxiety were to be expected. The 2/4th A.G.H. in Tobruk established a neurosis clinic in the early days of the siege. At first patients with nervous disturbances were treated in the hospital, which was within the town area, and later in a non-surgical section on the beach. Both sites were subjected to bombing with some loss of life, and superadded neuroses were seen in patients admitted for wounds or sickness. It was noticed that neurosis arising while men were in hospital was more likely to occur in the sick than the wounded. Infections appeared as a predisposing cause, in particular dysentery, and, in the early days of the siege, venereal disease. A treatment centre was then opened in an underground concrete shelter where there was safety, though the ward reverberated with shellfire and bomb explosions. This clinic was a divisional centre; no man could be returned to the base for psychiatric illness except through this channel. In the first three months 110 men were sent back out of 207 patients treated in this clinic. Facilities for treating such men in Palestine existed in the Australian convalescent depot, though delays in the sea movement from

Tobruk through Egypt to Northern Palestine were considerable and not calculated to improve the mental state of nervous patients.

Cooper and Sinclair followed up the work of this clinic and published a review of the results. The original version of this was not entirely approved by the general staff of the army, partly for security reasons and partly because of the frank description of certain types of fear state which it was thought might disturb morale. It may be remarked, however, that such descriptions were widely published in other parts of the world and were freely available to the lay press and public. Cooper and Sinclair considered that some factors in producing neuroses in Tobruk were the conditions of withdrawal from Cyrenaica, with risk of air attack and capture, lack of experience in some men of the partly-trained division, and the suspicion that no attempts were being made to relieve them once they had been shut up within the defence perimeter. They described "undisciplined and animal-like" manifestations of fear in some men under the stress of bombing raids to which no reply was possible. Dramatisation of their emotional condition was sometimes a feature, and some men had visual hallucinations. One occasional instance of the physical components of fear states was the recurrence of blood-stained stools in patients treated for dysentery. Men with uncomplicated fear states were not sent back to the base, and the diagnosis "fear-state" was written on their field medical card, so that any future assessments by medical boards would not be confused by vaguer and less accurate terms.

Of the 207 men analysed in this series 79 (38 per cent) were returned to work within the fortress area, and after periods of two to four months were still working with their units. Of the remainder 48 men treated at base were returned to duty with the classification "A" (fit for active service with field formations). An additional 48 were classified "B"", fit for base duties. Thus 61 per cent of the patients were returned to duty. Most of these men recovered quickly from what was only a temporary fear state; in others a morbid fear of shelling and bombing persisted. In others again an anxiety neurosis remained, some with associated physical symptoms. Anxiety states were by far the most common type of mental illness. Conversion hysteria was infrequent, 16 per cent; it usually occurred in young men. The outlook was not good with them on account of the liability of relapse. Few psychotics were seen, only four with schizophrenia and one with a depressive psychosis.

Care was taken in the original examinations to record the family and personal history of each patient in detail in order to ensure that a full record would be available to other medical officers. The desirability of continuity of treatment under the same attendants was recognised, but this is difficult to ensure in war. Fifty-eight per cent of the men examined were found to have some inadequacy of personality. In 23 per cent there was a history of previous breakdown, and 17 per cent of a severe head injury. As a rule these items in the patient's history had not been disclosed on enlistment.

Fear was one of the most important precipitating causes, but in this series physical exhaustion was not very significant, though some of the affected men had suffered from loss of sleep owing to the military conditions. Diet was not a factor; though monotonous it was of good quality and vitamin supplements, *B* complex and *C*, were given. It was noticed, however, that with some deterioration of physical condition, due to innate causes or to cumulative fatigue, the strain told more, particularly in those men who had defects of personality.

Cooper and Sinclair confirmed the general teaching that treatment to be effective should be begun promptly near the front line and continued as long as possible without intermission. Repeated examinations tended to confirm bodily fixations, even to create them, and prompt decision should follow prompt appraisal of each man's condition. The usual technique of explanation and encouragement was followed. In view of the limitations imposed by local conditions the results of work done at this forward centre were very good, though occupational and recreational measures were not readily possible in Tobruk, and could be applied only to patients sent back to the convalescent depot in Palestine. H. R. Love in a study of neurotic casualties in the field has added some interesting points about Tobruk. He considered that it was highly creditable to the morale of the force that there were not more casualties. In April 1941 the strain on the 2/4th A.G.H. was lessened by sending nervous casualties through the 2/3rd Field Ambulance. In five months 174 men were passed through; the mildly affected were treated and drafted back to the units. One hundred and forty of these men had anxiety states, and a large proportion of them had a history suggestive of previous breakdown. Age over 35 years was a predisposing factor. It is remarkable that eleven out of eighteen men with hysteria had a fugal syndrome. Treatment was carried out in dugouts and the position of the unit permitted some swimming. An effective form of occupational therapy was the employment of the men in building the dugouts in which they lived. Love, in emphasising the part played by fear in these states, suggests that an unduly sensitive fear reflex becomes facilitated, conditioning takes place from innate or external causes and finally infection or other mechanical factor may initiate a frontothalamic breakdown.

The importance of the continued effect of fear was well illustrated in naval experience. Men often had to be held on a ship still committed to combat and remaining in dangerous waters: it was found that under these conditions, fear states were often intensified and the patients needed more care and deeper sedation. This problem is further discussed in the history of the naval medical services.

Some difficulty was found in Tobruk as elsewhere when combatant officers wished to use medical channels for the disposal of unsuitable men. Where sufficient evidence of physical or mental unfitness could not be produced, this was of course inadmissible.

During the campaign in Greece few acute psychiatric casualties were observed, as might be expected in the midst of such swiftly moving events

which vitally concerned the well-being and safety of all members of the force. It was noticed, however, that many of the men on their return to Egypt and Palestine were exhausted and shaken. Had these men been then required to carry out responsible or tiring duties in less safe and comfortable places than training areas, the issue would probably have been different. The value of rest was well seen here. Its importance was also realised at this time under conditions of prolonged strain on ships, for instance those on the run between Tobruk and Alexandria. Such recurring strains made rest desirable after long spells of sea service, especially as breakdowns sometimes occurred after unduly prolonged periods of strain and even after the strain had been lifted.[1]

IN GREECE AND CRETE

Reverting to army experiences it will be noted that there were at least some favourable circumstances for recovery of exhausted men in the actions of Greece and Crete. Many men reaching Crete from Greece had an opportunity of resting there for a time until the terrific strains of the air invasion began, and those who escaped from Crete were quickly placed under conditions of safety and comfort once the often terrifying ocean crossing was over. Those who became prisoners of war are in a different category, for life as a war prisoner with all its trials and horrors does not characteristically produce neuroses of the usual civilian type. Australians who were ill or wounded or were returned to Greece by the Germans had the fortune to be cared for in a well housed hospital (2/5th A.G.H.) whose staff was singularly successful in maintaining the morale of its patients at a high level.

Another interesting feature of the retirement from Greece was the calmness of the nurses under the strain of a trying and occasionally dangerous journey. On their return to Egypt and Palestine they showed no evident trace of upset, being superficially at least most concerned about the replacement of lost belongings. This is of course what might be expected, as the nervous system of women resists strains of this sort remarkably well. Among some of the officers who had been subjected to great stress of responsibility signs and symptoms of an anxiety state appeared while on leave a little after their return. Examples of this latent period before the onset of clinical degrees of anxiety were seen in several soldiers of valiant character and strong personality.

IN SYRIA

During the brief Syrian campaign a considerable number of men with acute exhaustion states were sent down the short evacuation line to casualty clearing stations and hospitals in Palestine. Towards the end of the period the D.D.M.S. of I Australian Corps, after some delay due to transport difficulties, was able to establish a corps rest station. One of the officers

[1] It is interesting to note the record of two Royal Navy ships serving in this zone. James quotes them as only losing 5 men out of 480 as psychiatric casualties in two years.

of the field ambulance running this station was experienced in psychiatry, and useful preventive work was carried out there. It was thought that contributory factors to exhaustion were long marches, loss of sleep and other discomforts. Conversion hysteria appeared in rather increased numbers in the hospitals among these men: its well-known "infectious" nature demanded prompt treatment by suggestion and encouragement. Contact with the unsuitables who seek haven in hospital wards was specially avoided.

Analysis of 100 consecutive men from Syria with acute psychiatric disturbances at one A.I.F. hospital showed that 49 suffered from exhaustion states; 8 per cent of these had a background of instability, and the same proportion had recent infections. Most of this exhaustion group left hospital within a week. Forty-eight men had anxiety states, over half of them mild in degree. Of these 16 per cent had an unstable background, and 23 per cent had had a recent illness of some sort. Ten of them had hysteroid symptoms. The average age of the anxiety group was 25 to 27 years.

The immediate results of treatment of hysteria was good: symptoms included aphonia, anaesthesia, various palsies and an occasional fugue.

THE NEEDS OF 1941-1942

The need for more skilled psychiatric assistance was recognised at this time. The Consulting Physician to the A.I.F. reported that appropriate examination at enlistment should eliminate the over-age and the men with inadequate personality and history of previous breakdown, and advised that more specialised help was needed in the Middle East. The psychiatric adviser to the D.M.S., A.I.F., Colonel J. K. Adey, reported on the psychoneuroses in the Middle East in September 1941. He stated that about 20 per cent of men with combat exhaustion could be treated in forward areas and returned to their units, but that the more severely affected need treatment in hospitals. The latter were preferably sent as soon as possible to a convalescent centre where exercise and occupational therapy were prescribed under skilled guidance. Those improving sufficiently could then be returned to their units and others be brought before a medical board. As a matter of policy men under 40 years of age were retained wherever possible, even if classified "B". Older men and those with accompanying disease were returned to Australia. The object of this procedure was to discourage seekers after an easy way home, but it had the drawback of collecting numbers of men around base areas who were not particularly useful. Investigation showed that an unsatisfactory background was common among psychoneurotics, and also discovered a few men with congenital mental deficiencies which should have been a bar to enlistment. All psychotics were returned to Australia: in the majority of these cases war service played no causal part, indeed some of the patients had been treated for mental disease before enlistment. Colonel Adey in this report recommended that four more psychiatrists should be obtained from Australia.

Another measure taken to help the control of mental illness up to this period was the regular psychiatric examination of men in detention barracks whose record or conduct indicated some psychological abberration. For the further education of medical officers a medical technical instruction (No. 17 M.E. Series) was promulgated on the treatment of neuroses and a brochure on psychiatric casualties was distributed. Occasional instruction was also given by lectures. The official instruction simply set out the measures to be taken by medical officers in acute neurotic states, the emphasis being laid chiefly on rest, sedation and food. Obviously much of this work would fall on field ambulances, and in order to maintain continuity the policy was for these field units to retain such men as they could who were recovering rather than to pass them on in a stream to a casualty clearing station. At the C.C.S. a period of three days was advised, after which a man who had not recovered should be sent to a hospital. The booklet referred to was compiled by the Consulting Psychiatrist to the British Forces in the Middle East, and described in some detail the signs and symptoms of neurasthenia, reactive depression, hysteria, anxiety neurosis and obsessional and compulsive states. Epilepsy and self-inflicted wounds also received special mention. The division of military mental disorders into action or combat neuroses and other sickness due to neurosis was clearly pointed out, and the cause of breakdown traversed. Treatment, of both preventive and curative type, was adequately described. Welcome personal help was also given by this consultant, especially in the earlier days before the Australian force was more or less self-contained. The influence of a psychiatric consultant to the A.I.F. who could give his whole time to instruction and clearing up problems was really needed at this time.

A word may be said here about self-inflicted wounds. These were observed as early as January 1941 in more than one unit outside Tobruk, later at one stage of the siege of Tobruk, and occasionally in other combat areas; occasionally self injury was also seen in troops in base areas. Official enquiry was always made and some of these men came also before medical boards, but it is a pity that no systematic psychiatric investigation of these men was undertaken.

EXTENSION OF PSYCHIATRIC SERVICES

Meanwhile in Australia plans were being made for the extension of the psychiatric services of the army. Following the meeting convened by General Downes further steps were taken by Major-General Maguire, who had then been appointed as D.G.M.S. at army headquarters. Advisory committees on "war neuroses" were set up in New South Wales and Victoria. Most of their activities were directed towards the provision of accommodation for military mental patients, and the establishment of special psychiatric sections of the base hospitals in the capital cities. Maguire laid down procedures for the reception and disposal of psychiatric casualties from overseas as a guide to the deputy directors in the military districts. In view of the differences in existing legislation governing

mental hospitals in the different States an amendment of the supplementary National Security Regulations was made a little later. This permitted admission of service patients to mental hospitals without certification, and also allowed the States responsible for such care to apply their usual powers, provided the medical director of the Service in question was notified of any moves, leave, or discharge of any such patient from hospital.

Steps were taken to provide suitable occupational training at base hospitals. The question of psychiatric group-testing of recruits was also discussed, and also the best methods of instructing all medical officers in the rudiments of psychiatry in the Services. This last was of course very restricted in its influence; what was more useful was the intensive training of a number of medical officers in psychiatry. A three months' course was arranged, and later eight officers were trained, four in the A.I.F., one in the navy, and three in the air force. This policy might have been applied even more vigorously for, in spite of discernible attitude of distrust in and opposition to the work of such partly trained officers, they were of distinct value. It was of course understood that psychiatrists could not be fully trained by such brief special courses.

In response to the request for more psychiatric help Lieut-Colonel W. S. Dawson (Professor of Psychiatry in the University of Sydney) was sent to Palestine, where he took over direction of the neurosis clinic at the 2/1st Australian Convalescent Depot at Kfar Vitkin on the northern coast of Palestine. Major R. Whishaw had previously established this clinic within the convalescent depot after many difficulties and frustrations, and by the end of 1941 had the help of two other physicians trained in psychiatric work, Captains A. J. M. Sinclair and G. B. Murphy. None of the officers of this clinic were officially entitled psychiatrists; officially they merely worked as medical officers to the clinic. The number of psychoneurotics was for some time more than the available staff could handle, but Lieut-Colonel Dawson with the further help of Major A. Stoller obtained better conditions. This clinic was at first attached to the convalescent depot, but the commander of the depot, Lieut-Colonel G. Burston, and the medical officers were dissatisfied with its location. Access to alcohol and gambling were serious handicaps to its work, and immunity from ordinary punishment for misdemeanours made the inmates undesirable contacts for other convalescents.

In December 1941 the centre moved to Nathanya where there were better facilities for exercise and occupational work, including instruction in various trades and technical callings. The previous title of "war neurosis clinic" was changed to the "psychiatric centre"; this was highly advisable, for "war neurosis", in itself an inaccurate name for conditions not necessarily related to war at all, is highly undesirable when describing a clinic designed for the rehabilitation of men with a wide variety of psychiatric states. In the first six months 528 officers and other ranks were examined there and 326 discharged. A physical and mental investigation of each man was made, and a copy of the findings supplied to the Medical

Board before which he appeared. Medical boarding of all nervous and mental patients was carried out at this centre. The scope of treatment was widened, and "Cardiazol" was used for shock therapy, "Somnifaine" for narcosis and insulin for full coma in a limited number.

Difficulties still arose over some matters of discipline, as delinquencies were often pardoned because the men were neurotics. This centre did some good work, particularly in its thorough investigation of the patients, and helped to emphasise the value of occupational therapy, which was beginning to be more used in military hospitals. Workshops for carpentering, plumbing and engineering had been established by Major Whishaw, but their work was hampered by lack of funds. In this connection the difference between true occupational treatment and diversional activities was not always strictly enough drawn. It was noticed when classes in arts and crafts were started at Nathanya with the help of the Red Cross Society that more men became interested in these than in the courses which involved more personal effort, and incidentally, were much more realistic in nature. The chief difficulty in the working of such a clinic was also its essential weakness, its distance from the home base. It was recognised that the sooner psychotics were sent home the better. With psychoneurotics the position was really more difficult, not only because of their greater number, but because every patient with a condition of the severer type awaiting return, even though relatively calm and comfortably occupied, was a possible hazard to the recovery of others. Even though three hospital ships were now available, their prompt return to Australia was not simply secured. Delays were a complicating factor in recovery for it is probable that most of the success of psychotherapy in these circumstances rests (in Dawson's words) "essentially on the fact that the patient is or soon will be downgraded so that he is removed from the stresses and situations he fears, or feels unable to face".

It was indeed suggested that a centre should be opened at Asmara in Eritrea, where the 2/5th A.G.H. had been stationed as a base for the longer term invalids, but this would surely have accentuated this difficulty. The same problem, more subtly concealed, arose in convalescent depots amongst men not obviously of psychoneurotic type. Earlier in the year 1941 Colonel Hailes, Consulting Surgeon to the A.I.F., commented on the vicious circle of convalescent depot, training unit, hospital, convalescent depot—a chain which needed to be broken. He remarked that very few of the average patients at the convalescent depot at Kfar Vitkin spent time on the beach, in spite of the ideal conditions there. This weak spot in the scheme of medical care is really a reflection not so much on the system of medical care as on the inability of average persons to use and enjoy leisure.

IN THE WESTERN DESERT IN 1942

In 1942 after the return of most of the A.I.F. to Australia, the 9th Division remained to take part in the next phase of the desert campaign which finally pushed the enemy back. In this the division was faced with

action conditions of a different kind, in which it was part of a large force exposed first to the danger of being over-run by a powerful and highly mobile army, and later to a more prolonged engagement of great magnitude and severity. A conference of physicians was held in Cairo early in 1942, and amongst other subjects the types of neurotic illness seen on active service were reviewed. Emphasis was laid on the need for recognising the men of poor mental make-up, fit for little in active warfare, and the maladjusted. The importance of fatigue and illness as predisposing causes of breakdown was also stressed, especially in view of the opportunity given to prevent or forestall true combat neuroses.

When the division went to the Western Desert in June, fear states were again encountered. The men were treated in units as far as possible, but the noise of bombardment was often too great to make local treatment successful. Where it was not convenient to keep them in slit trenches near the R.A.P. they were sent to rearward positions. Some prophylaxis was found possible: many of the men likely to break down could be picked beforehand, and commanders often helped by sending fatigued men to the R.A.P. for a rest, which often restored them completely. When combat stress showed up men likely to become a liability, attempts were made to reclassify them if sufficient evidence could be obtained from officers and N.C.O's. The prolonged strain of the El Alamein battle caused the breakdown of numbers of men of certain units engaged in heavy fighting. A rest camp was established on the coast and was very useful: here psychiatric casualties needing treatment in hospital were held until the battle casualties had been cleared. At this rest station over 200 men marked "N.Y.D.N." (not yet diagnosed nervous) were classified and dealt with.

The value of early treatment and disposal of men suffering from exhaustion and fear states was well seen in the work of a psychiatric first aid post established by the 2/3rd Australian Field Ambulance. Major Stoller was seconded to take charge of this post, where he treated over 100 men, most of whom could be dealt with on the spot. The number of these men sent to hospital was very small and of those who subsequently appeared before medical boards was negligible.

Some medical officers held that too serious a view was taken of the conditions of patients sent back from some units. One battalion medical officer remarked that some of them reached medical boards classified as "anxiety neurosis" or "depressive state", whereas in Tobruk similar conditions were classed as fear states and the men returned to their units after treatment.

It is curious how reluctant we have been to acknowledge fear in medical terminology. We agree with the aphorism of Leonardo da Vinci, "Fear springs to life more quickly than anything else", and recognise it as a primal instinct, yet we hesitate to be frank when it obtrudes its universal influence into diagnosis and prognosis.

Hospital treatment for psychiatric casualties from the Western Desert was at this time undertaken at the 2/6th A.G.H. at Gaza and the 2/7th

A.G.H. at Rehovot and later at Buseili. The work of the psychiatrist centre at Nathanya correspondingly lessened, as it now served only one division, and useful work was carried out in the hospitals without much further transfer of patients.

The 9th Division, after its assignment was fulfilled, returned to Australia in 1943, where all available forces there were engaged in the defence of Australia and in the war against Japan.

PSYCHIATRY IN THE SOUTH-WEST PACIFIC

Early in 1942 psychiatric problems arose in the Pacific theatre of war. Questions for solution were the manner in which mental casualties should be dealt with in the forward areas in the Pacific theatre of war, and how these men were to be transported to a forward base, where necessary treatment could be given until they were sent to the base military hospitals in each State capital city. In all these base hospitals in Australia psychiatric services were soon available, varying with the size and priority of construction of the hospitals in different cities. Where full-time psychiatrists were available they were employed, and elsewhere visiting consultants and full-time physicians with psychiatric experience did the work. As in other specialties, there were distinct advantages in having full-time specialist officers as the size of the clinics grew. The expansion of the forces made the existing scarcity of trained psychiatrists even more acute.

It should be noted that for the first time in this war Australian volunteer and conscript forces were involved together in active military service. In New Guinea and the other islands the technical experience of the Middle East was more or less repeated. Psychoneuroses were more common in the base areas, and the problem of "B" class men with somatic fixations again arose when they were employed at forward bases. Indeed this became more acute owing to the policy of employing more "B" class men in base duties as the armed forces grew in extent. Psychoses on the whole were uncommon, but the relative and absolute increase in numbers of acute psychotic states of schizoid or confusional type was noteworthy. This condition had been noted in the Middle East, though only in small numbers; indeed it might perhaps have been predicted from previous experience in the 1914-1918 war.

Once more exhaustion and fear states were encountered in difficult combat, but these were fewer in number, and tended to appear in actions from which, although they were longer drawn out, relief was not to be expected. Infections were again noted as a contributory cause of breakdown. The great increase in skin diseases in the island introduced another factor of some importance; these conditions interfered with comfort and often caused anxiety to the patient. Conversely, it may be noted that repeated assaults on the nervous system may be a contributory factor of some importance in producing some dermatoses.

In forward bases which later became stable bases, such as Port Moresby, anxiety and fear states were commonly seen in the hospitals, with or without somatic symptoms, but hysteroid and confusional conditions were

rare. The convalescent depot in the Moresby area was at one time so near the advancing Japanese that it had to be moved temporarily, but it was interesting that in spite of this there were no adverse effects on the morale of the patients. This is no doubt a tribute to the men and also to the manner in which the unit was run. In an analysis of 100 consecutive patients needing psychiatric attention Captain A. G. Cumpston reported that over one-half were temperamentally unstable, and one-quarter had anxiety states. This total only comprised 1.6 per cent of the total admissions to the depot. Many of the unstable groups had a previous history of neurosis, but they had sustained the demands of civil life better than the restrictions of a disciplined army. Most of these patients showed satisfactory improvement under a regime of physical and mental activity.

During the Owen Stanleys campaign few neurotic casualties were seen; Robinson records that he saw only three who needed evacuation. In an action which called for fortitude and unselfish endurance of a high order, this again reflects the spirit of the men and their leaders.

During 1943 not many psychotics were seen, but as in the Middle East there was a certain troublesome proportion of these, whose acute confusional or manic episodes required control in a strong room or with restriction gear of some kind. Restraint of a violent man in a tent or fragile hut was a trying experience, even with powerful sedation, but forcible restriction was used as little as possible.

During 1944 a higher proportion of psychotics and acute manic states was seen: at the 104th C.C.S. at Aitape for instance, in 1944-1945, the need arose for special equipment. Early in 1944 the need for more skilled psychiatric help was felt in the corps area, but none was available at the time simply through shortage of staff. At Lae, which became the main forward base for New Guinea, accommodation for psychiatric patients was provided. There was still need for adequate training of medical officers, particularly those of forward combatant units, in the handling of psychiatric patients. The D.D.M.S. of Corps suggested that medical officers be attached to special centres for experience, and arranged for clinical meetings at hospitals to supply part of this need.

Later still at Bougainville acute psychoses were still common, chiefly confusional in nature. A psychiatrist attached to the hospital there was found most valuable. It was interesting that a series of gross hysterical states was observed here at a time when anxiety states were rare. This increase in hysteria is in conformity with experience in other New Guinea campaigns. The 2/9th A.G.H. and 2/5th A.G.H. at Moresby on occasion had their accommodation taxed. At the latter as many as 30 psychotics were sometimes under treatment, up to 20 being of acute and violent type, with only six single rooms available. Some 15 per cent of one observed series of psychoneuroses were hysterical in type. Sinclair notes that the incidence in officers exceeded that of other types of neurosis. The most frequent phenomena encountered were speech disturbances and alterations of consciousness such as amnesia. Actual fugues were rare. It was interesting that during unremembered periods when the soldier's

actions could not be positively traced, no additional risks seem to have been incurred by him, showing the curious semi-purposive nature of hysterical reactions Occasional convulsive attacks were seen in both frontline and base troops due to this cause, but never during action. Motor palsies were rare. Functional analgesia occurred at times; it was noted in a number of otherwise healthy soldiers in a group being investigated for thiamin deficiency by tests of sensation in the lower limbs.

It may be recorded here too that cardio-vascular fixations in anxiety states were much commoner in New Guinea than in other combat areas. Sinclair noted a 20 per cent incidence in New Guinea, but only 12 per cent in Palestine, 8 per cent in Australia and 5 per cent in Tobruk. Fitts has remarked that effort syndrome is now rare because the modern army does not march, and this bears out the same idea. In New Guinea even fit men frequently experienced breathlessness to the point of discomfort or even distress in that difficult country, and it is easy to see how a fixation might arise from the heaving chest and the pumping arteries.

In June 1945 at Morotai, which was purely a forward base, patients with confusional or manic states were again encountered, and lock-up cells, not included in the original plan of the hospital, 2/5th A.G.H., were much needed. During these periods in the islands the number of neuroses was relatively decreased, while a certain absolute and relative increase occurred in psychoses. Occasionally too mental defectives were still found among recent recruits. Men were even enlisted and classified "B" in spite of the record of a deficient mental state on their papers.

The acute psychotic states at this time raised a number of problems: these were the nature and cause of these illnesses, the best method of handling, and the transport of the patients to the mainland. The two latter were pressing, especially in a place as distant as Lae from the hospitals on the mainland equipped for psychiatric treatment. The only immediate question involved in the cause was whether there might not be some discoverable toxic factor. Atebrin was thought of, but it cannot be blamed as a significant cause of psychosis. Confusional states were observed in men on high atebrin dosages well above the level required for the suppression of malaria, but these were not the same as the psychoses. The pattern of toxic confusion due to atebrin was rather distinctive: in particular the patient had insight into his own mental state and might seek advice on that account. Moreover, all psychotic patients in a malarious area received routine suppressive doses of atebrin without any adverse effect on their mental recovery.

Before further consideration is given to the nature of this psychosis some of the difficulties in disposal of these patients may be discussed. At the 2/7th A.G.H., before June 1944, psychotic patients had been kept in an annexe to a general medical ward, and were transferred to the mainland as soon as possible. But the numbers began to rise and transport became increasingly scarce. A special ward was then built with ten lock-up cubicles, a great relief to the staff who, while waiting for its completion, treated fifty-one psychotics in tents. This period was very trying to all concerned,

but it gave opportunity to study the course of the disease when uncontrolled save for sedatives. When a ward of thirty beds was available, with adequate staff and facilities, convulsive therapy by "Cardiazol" was introduced in order to make the patients more amenable to travel. The beneficial effect on the psychotic state was soon apparent. Of the fifty-one men treated before this time, twenty-six had been admitted to hospital under restraint in order to make travel possible. An attempt was made to return eighteen of these patients to the mainland by air, but the first experiment was a harassing experience for the medical officer in charge and the aircrew. It was already known that these men were intolerant of air travel, from experiences during their removal from forward areas to the hospital. The long and inevitable delays occurring at airfields increased this trouble, and patients leaving a medical unit quiet under sedation often became maniacal when in the air. The hazards of mechanical restraint were considerable, too, and peripheral pressure palsies sometimes could not be avoided. The physical condition of the patients was often worrying. Their body temperatures often rose and they became dehydrated. Long journeys were particularly unfavourable in this regard. The anxieties of this experimental flight were too great to be repeated. There were no facilities for giving intravenous sedatives or other medication, drugs were not taken well by mouth, and morphine and hyoscine caused circulatory and respiratory depression at higher altitudes. However, instructions were given that air transport must be used for these patients, and it was imperative that early active treatment should be undertaken in New Guinea. Consequently "Cardiazol" treatment was begun in Lae. Of 236 psychotic patients, of whom 124 needed restraint on admission, 142 were treated by convulsive seizures, with such success that only sixteen needed restraint during their subsequent journey to the Australian mainland. Improvement was usually evident after three treatments, and was often dramatic, and injections were continued twice weekly until a plane was available. A few of the usual traumatic complications occurred, but no serious trouble remained. Sedatives were little required: paraldehyde was used if the need arose, as barbiturates had an unwelcome inhibiting effect on convulsive therapy. Fever was not uncommon on admission to hospital; this was seldom due to malaria, but to undue psychomotor activity in a hot humid climate. The free use of intravenous injections of glucose and saline relieved the dehydration so often present at this stage and was most beneficial. Suppressive atebrin was continued as a routine.

Further precautions were taken during the journey by air. The experience of the officers of the air force medical evacuation unit showed that it was important not to allow the mental state of patients to divert attention from their physical condition, as it was usually this which needed special care. In order to combat the proven lowering of the glucose reserve during and after manic phases of psychotic illness large doses of glucose were given by mouth to patients before they embarked on a long flight. If time did not permit thorough preparation, intravenous infusion of glucose and saline was given. It was important too to limit those factors which might

cause disturbance of heat regulation; canvas jackets were abandoned as a means of restraint, and towelling securing the wrists and ankles substituted. Intravenous "Sodium Amytal" was used occasionally for very restless men. Adequate spells of rest were found to be advisable on a long trip. The adoption of these measures revolutionised the treatment of psychotics in relatively forward areas, and experience showed that early convulsive treatment was an important factor in producing prompt remissions and in improving the prognosis of the illness.

Mention may be also made of psychiatric experiences in the operations in Borneo, in which two divisions were engaged. From these over a period of twelve weeks 360 men were sent to hospital with psychoses and psychoneuroses, the proportions being one psychosis to four neuroses. At least 60 per cent of the psychoses were of the schizophrenic type. In most of these electro-convulsive treatment was used before evacuation, and again the results were very good except in the depressive psychoses. In general, remissions were secured by early treatment, transport was facilitated and the degree of mental deterioration was lessened. Battle exhaustion also occurred in the Borneo actions, but education of the medical officers and a general understanding of the prophylactic measures caused a lowered incidence. It must be realised too that these operations, though producing some acute situations, were conducted on a rising wave of success, with efficient preparation and mastery of land, sea and air.

Some psychotics were also evacuated under restraint and heavy sedation without other preliminaries. Here the experience of the medical and nursing staffs of the R.A.A.F. medical services was of the greatest help.

A detailed analysis by Curtis showed that of 480 men seen in hospitals over a six months' period 144 were psychotics, 56 psychopathics, 270 psychoneurotics and 10 mental defectives. Of the neurotic group 206 out of 270 had anxiety states (including fear states), 25 hysteria and 20 neurasthenia or reactive depression. Of 343 psychiatric casualties seen at one hospital from 28th May to 8th October 1945, poor or bad home environments existed in 41 per cent. Battle stress was non-existent in half the total number, and severe in only 9 per cent. As an illustration of the difficulty in predicting a man's reaction to combat stress from knowledge of his history and personality, a few men with poor backgrounds broke down under heavy strain after having passed unscathed through engagements in other campaigns. The importance of continued or recurring strain was no doubt considerable. Insulin to sub-coma level was used for selected patients, and abreaction induced by pentothal for some of the acute fear states.

PSYCHIATRY IN PRISON CAMPS

In Germany and Italy the general conditions of camps for prisoners of war were far more humane than those conducted by the Japanese. Camp 57, at Gruppignano in Italy, was an example of a camp where conditions were poor and administration harsh and severe. Captain E. W. Levings noted here that the proportion of psychological disturbances among some

5,000 men was much higher than in better camps, such as those in Austria, but nevertheless the incidence of psychiatric states was very low. Even after nearly two years Major R. T. Binns records that only 8 definite cases of psychosis were recognised among these men of the 6th Division.

A different mental environment was experienced by the 8th Division in action and later in captivity. In Malaya these men experienced battle stress, the frustration of surrender, privation and cruelty, and dispersal of its force, conditions which imposed the severest strains on morale. C. R. Boyce has described the remarkably low incidence of psychiatric illness in this force. Before the outbreak of hostilities 165 patients with neurotic manifestations passed through the 2/2nd Australian Convalescent Depot. These were of the already familiar types, with one interesting feature, the universal existence of some degree of amnesia, attributed by the men to local conditions. During the brief action on the peninsula 89 patients were examined, and under great difficulties 51 were investigated. These men had suffered varying degrees of combat stress, but as the conditions at the depot were regarded as no better than those in the men's units, little rest could be assured. Notwithstanding this drawback, satisfactory results were obtained by treatment directed along the usual lines.

Under the rule of the Japanese the factors productive of mental disabilities were different. The natural depression resulting from military failure, loss of liberty, lack of news from home, and uncertainty of the future, were common to all prisoners of war. In addition there were the factors of inadequate diet, absence of hygiene and comfort, and inhuman treatment. Certain features were more or less common to all the psychoneurotic states seen in the force. All neuroses were of depressive type. Somatic symptoms commonly included rapid heart action with some subjective disturbances and muscular weakness. Continued physical strain and lowered nutrition doubtless had a determining influence. Headaches, tremors, even affecting the voice, and hysterical manifestations were also common. Disturbances of cognition were seen, such as amnesia, confusion, retarded ideation and lessened concentration.

The prisoners in fixed camps showed a good morale, and the high standard of discipline insisted upon by their commanders helped them greatly. In the working camps the conditions were usually very much worse, but in general the incidence of mental diseases of all kinds was extraordinarily low. In Nakom Paton, the huge hospital compound where gathered most of the survivors of those fallen ill in the railway working camps, a number of men with temporary disabilities were put into the mental compound, either because of fear states due to bombing or delirious conditions not specially connected with other disease. Fisher noted that this type of delirium was not associated with systemic disease: it was not seen in proven malaria, but appeared in overwrought men occasionally, usually producing some delusional ideas. After liberation had come to this camp all of these men were released, as they had been confined only for their own safety. There remained only 34 men with psychoses. Boyce treated only 11 psychotics in Changi in the first fifteen

months, drawn from 15,000 Australian prisoners. Four Dutch and 18 British patients were also seen. In all 31 psychotic patients were seen by him and 3 psychoneurotics. No facilities for special treatment existed, but as good a diet as possible was given, and all practicable social amenities were provided and participation in group diversions encouraged.

It would be difficult to arrive at any accurate figures of the incidence of psychoneurotic states in the 8th Division, having regard for the poor state of nutrition of the men, and the high rate of sickness, particularly of infective nature and remembering also the high death rate. But there is no doubt that nervous and mental factors in the production of illness were in the comparative sense very slight. Even admitting that a grim struggle for existence and neurosis are not readily compatible, the psychiatric history of the 8th Division is also a tribute to its high sustained morale.

PSYCHIATRIC CONDITIONS IN AUSTRALIA

Let us now turn from the forward action areas to the mainland of Australia, where the great expansion of the armed forces in Australia from 1943 onwards greatly increased psychiatric work. Many patients needed investigation, and had to be treated locally or sent, often over considerable distances, to larger centres. These patients ranged from those with mild somatic symptoms or anxiety, to violent psychotics. In base areas neuroses of the civilian type were common, and here helped to swell consultative clinics. It is of some interest that among the female staff of hospitals established for the care of servicewomen, neuroses had a high incidence. These women were themselves members of one of the women's services, and contributory factors were home conditions or the other familiar factors of emotional stress and isolation. Fixations of a gynaecological kind were of frequent occurrence.

Apart from these manifestations of mental maladies in the thickly populated centres, special problems arose in several parts of Australia, particularly in the Northern Territory and Queensland. In the Northern Territory troops had been stationed from the early days of the war, in view of its relative vulnerability. The men felt a degree of futility in their military life there, they were isolated, local amenities were somewhat limited, and in some parts of the year the weather was hot and trying, though not more so than in many other parts of Australia. When the Japanese raided Northern Australia from the air there was at first a sharp reaction, particularly among the civilian population. The atmosphere had changed, but largely for the better. There had grown up in Northern Territory a bogey based on an assumption that the conditions were bad there. True, life was monotonous, but there was little if any warrant for the tradition that that vague entity of the text-books "tropical neurasthenia" flourished there. Even medical officers at times advocated that men should be sent south to rehabilitate after attacks of mild illnesses like dengue fever. Yet had they known Chesterton's words these men might have applied to themselves his couplet:

"The earth is enough and the air is enough
For our wonder and our war."

The remedy for this was in the hands of the force itself, and when the correct outlook was applied practically the importance of neuroses decreased. Colonel N. D. Barton, the D.D.M.S. N.T. Force, remarked in 1942 that "tropical neurasthenia" increased as temperatures rose, and commented on the importance to morale of physical factors such as cleanliness, care of the skin, and adequate supply of water and salt. Regular mail and good amenities were important, so too was the elimination of ineffectives from the force. It is again interesting that this much publicised tropical malady did not appear among the nurses. The same observations applied with equal force to other areas. It was noticeable that similarly trying climates and local conditions were better tolerated where there was more military activity.

Of course it is freely admitted that prolonged periods of inaction in an uncomfortable climate cause deterioration of health of the mind-body entity. A special technical instruction drew the attention of all medical officers to their duty in assessing mental and physical fitness in the tropics. The Director of Medicine, however, discouraged the carrying out of regular surveys for that purpose, knowing the ease with which suggestions of sinister significance may be attached to such routines.

In North Queensland large training areas were established on the Atherton Tableland, where two divisions could be accommodated for training or rehabilitation, and considerable bodies of troops were concentrated in other areas. In the hospitals of these areas, as indeed all over Australia, consultants visiting medical holding units found many beds occupied by patients with psychogenic maladies. In some hospitals patients with similar somatic complaints or at least with similar somatic diagnoses were admitted to the same wards for alleged ease of organisation. This applied particularly to the digestive diseases. Numbers of psychoneurotics found their way to these wards where there was a real risk of their confirming their fixations. Even negative results of special investigations might have this effect. A technical instruction (No. 9) was issued dealing with the management of the soldier with dyspeptic symptoms, and the indiscriminate admission of such patients to a dyspeptic ward was forbidden. It would be interesting to know how far dental care and dietetic improvements reduced the incidence of dyspepsia.

Facilities for psychiatric work on the Atherton Tableland were limited. At the 2/6th A.G.H. patients with acute mental states had to be held in tents, and moving them was slow and difficult. Sedation and convulsive therapy with "Cardiazol" were the only active methods of treatment available.

PRE-SELECTION

In 1943 some forward steps were taken in two directions, by preventing the induction of recruits unsuitable from the point of view of mind and personality, and by extending facilities for treatment of mental illness.

Efforts in the preventive field were intimately concerned with the development of psychological services in the Australian Army. The gradual evolution of these services has been described by Lieut-Colonel J. V. Ashburner from the early application of psychological testing for selection of aircrews in the R.A.A.F. to the formal establishment of a psychology service in the Australian Army in February 1945. Before this, civil industry had made cautious trials of such methods of selection, and civilian psychologists were banded together as a Volunteer Emergency Psychological Service during the earlier war years to assist in certain service problems. These problems were chiefly those of selection of staff for highly technical work, as in survey and signals units, and also those concerning the choice of the most apt procedures for army selection. In 1942 an Advisory Committee on Psychological Testing was formed which gave advice on the organisation and procedures necessary for such selective work.

The rapid expansions of the armed Services and war industries, particularly of the army after Japan entered the war, made correct allocation of men even more important, and a staff officer (Major H. L. Fowler) was appointed to organise the introduction of psychological testing procedures. Later Lieut-Colonel Ashburner took over this work. In September 1942 a psychological section was formed at Allied Land Headquarters in the Directorate of Recruiting and Mobilisation, and shortly after this testing sections began work in the eastern States. The volunteer body in Sydney had already been helping in carrying out aptitude tests, in which its members had accumulated valuable experience. Within six months all States were covered by the services of this section, and recruits and re-allocated men were subjected to a degree of psychological control. Investigations of delinquents were also begun. Though the work of the psychology section helped to raise the low standard of pre-selection it was hampered by difficulties in obtaining enough adequately trained testers, particularly in the field of emotional maladjustments.

By the middle of 1943 pre-selection boards for officers were introduced, and the need for vocational guidance of re-allocated men and of discharged men coming under the care of repatriation suggested further expansion of the psychology service. So far the work of this technical service was non-medical in its application, but where disorders of personality were suspected, or where deficient mentality was disclosed on testing, the need for psychiatric guidance was felt. Evidencing the need for this work, Major Youngman, psychiatrist attached to the First Army Psychology Section, found that of 103 men discovered to be abnormal, most had neuroses, but the majority had a mental defect as well, or were simply mental defectives without stability. In Victoria late in 1943 medical boards and the psychologists were not always in agreement. A special report to the D.G.M.S. Army by Major J. F. Williams pointed out that the lack of psychiatric facilities forced the psychological section to undertake diagnostic work which was really the province of a psychiatrist. A visiting psychiatrist was then appointed to examine men whose response to routine tests suggested mental abnormality. A psychiatrist and a psychologist were

also attached to the officers' pre-selection board, which began work in October 1943. More cannot be said here about the work of this board. Administrative complications prevented a critical test of the accuracy of this selection of candidates for admission to an officers' training unit, but the high percentage of passes of these candidates from the school was at least encouraging.

With regard to the success of preventive measures in excluding unsuitables from the Services, it is not possible to present any statistical evidence, but the impression was gained that the chief advantage accrued from the more correct allocation of men. The Royal Australian Navy using only volunteers did not feel the need for special pre-selection so much. The numbers were small and the fields of choice wide. In the R.A.A.F. special attention was given to certain aspects of pre-selection particularly for air crew, pilots, air gunners and air observers. Some automatic selection of recruits for these Services helped to reduce the numbers of men more likely to become psychiatric casualties.

The need for increased therapeutic facilities had been under attention for some time. Reference has already been made to the consideration of hospital accommodation for psychiatric casualties in Australia. Base hospitals in the capital cities had some special accommodation available, though this varied in the different centres. These hospitals could not be expected to act as other than clearing and diagnostic centres, or to treat patients other than those likely to be only a short time in hospital. Psychiatric clinics were set up in a number of convenient places, and used largely for diagnostic purposes. The work was done by full-time medical officers with psychiatric experience, in some instances by fully-trained psychiatrists. Visiting consultants assisted in directing these activities. In Western Australia psychiatric patients were admitted or transferred to the base hospital in Perth, or 108th A.G.H. at Northam, and were treated there, but no facilities existed for acute cases: these patients were sent to mental hospitals. One special convalescent home for psychiatric patients was established at "Rockingham" in Melbourne by the Red Cross, and here occupational work was carried out.

FURTHER PROBLEMS IN AUSTRALIA

It is natural that the most acute psychiatric problems in the Services in Australia should arise in Queensland, where large bodies of troops were concentrated, and where most of the returning sick found at least temporary accommodation. During 1943 some publicity was given in the Press to questions of psychiatry in Queensland, and the D.G.M.S., Major-General Burston, deputed Major J. F. Williams to report on the situation. Williams found that the difficulties in the handling of the psychiatric patients were many in the northern parts of Australia, and that extemporised methods were under existing conditions unavoidable. Good environmental conditions could really be obtained only in base areas.

There were special reasons for these difficulties. The important areas near the Queensland coast were potential target areas, and for some time

it was doubtful whether the construction of a base hospital would be continued at Brisbane, or whether Toowoomba and other inland towns would be regarded as the official bases for hospital treatment.

At 112th A.G.H. in Brisbane (Greenslopes) psychiatric patients became an embarrassment, owing to their number (about 25 per cent of the total bed state at one stage) and to the limited accommodation for acute psychotics. A visiting consultant attended twice a week. Therefore psychiatric patients were transferred to Redbank near Brisbane, to the 7th Camp Hospital. For a time here facilities were very inadequate, until in May a psychiatrist (Major G. B. Murphy) was appointed to the medical staff. Before this only periodic visits were possible by a consultant and by the Superintendent of Goodna Mental Hospital, who were unable in the time at their disposal to cope with over 200 patients. Acute psychotics were transferred to Goodna, and here some 60 to 70 patients awaited submission to overworked medical boards. The appointment of a full-time officer at the 7th Camp Hospital made early treatment more possible, and here with little assistance and by dint of personal training of staff he carried out good work, using insulin coma with satisfactory results.

In the other hospitals of Queensland many psychiatric patients were occupying beds at this time. In 2/11th A.G.H., for instance, at Warwick, in four months psychiatric patients filled about 10 per cent of non-malarial medical beds. In Toowoomba in the 117th A.G.H. this percentage rose to 25 per cent. On the Atherton Tableland also consultative clinics dealt with large numbers of men with varying degrees of neuropsychiatric disorders. There were no facilities for caring for acute psychotic casualties on the Atherton Tableland, where two divisions could be accommodated for rest, rehabilitation and training.

It was evident that there was great need for a hospital which could undertake the care of psychiatric patients. This need was supplied by the taking over of the Kenmore Mental Hospital at Goulburn, N.S.W., and its equipment as an army general hospital. Here, in addition to general medical beds, there were wards for dermatological patients, but these occupied only 27 per cent of the medical bed space, the remainder being reserved for psychiatry. In quiet and suitable surroundings with gardens and attached farms there were full facilities for all types of treatment, carried out by an adequately trained staff. The work at Goulburn, begun under Lieut-Colonel Gwyn Williams, continued under Lieut-Colonel A. J. M. Sinclair; it was of great interest as all aspects of mental treatment and rehabilitation were covered. Here, and later at Ekibin in Queensland, most of the major psychiatric casualties were handled for the eastern States. The difference made by good facilities was well illustrated when the hospital site of Ekibin near Brisbane was taken over by the 102nd Australian General Hospital from the American Army Medical Corps. Work was carried out here in excellent buildings, with ample accommodation and air conditioned rooms. At Goulburn temporary attachment of U.S.A. medical corps psychiatrists was found to be of great mutual benefit. A sergeant from the 2nd Australian Psychiatry Section was also attached

to the staff and was most useful, particularly in the testing of mental defectives. In three months 154 patients were psychologically tested for mental age, evaluation of personality, intelligence and aptitude. Large numbers of psychoneurotics and psychotics were treated at Goulburn till after the end of the war, when the Repatriation Department was able to assume the responsibility.

General physical treatment and psychotherapy were used. The latter was superficial, no deep analyses being attempted. Interviews were given every few days, and ample time allowed, from fifteen minutes to an hour. With psychoneurotics the amount of explanation added to encouragement depended on the educational level of the patient; with both neurotics and psychotics the opportunities for occupational treatment were fully used.

With psychotics electro-convulsive treatment and insulin coma were used either separately or in combination. The former was not regarded as the ideal and only method for treating schizophrenia, but as a prelude to insulin full coma. A full course of shock therapy usually included ten shocks: it was valued for the improvement which followed, making patients more amenable for further treatment. The hazards of these methods were not found to be undue. About 20 per cent of patients showed radiological evidence of compression of the bodies of thoracic vertebrae, following convulsive shocks, but few symptoms were observed, no treatment was given and no sequels were noted. As many as eighty patients a day were given full coma insulin treatment. Four deaths were reported from 114th A.G.H. up to December 1945, a mortality rate closely approximating to that found in Great Britain and U.S.A. Consideration was given to the possibility that fatal results might be related to a fall in plasma proteins, as this had been described in such patients with circulatory failure. In general full insulin coma gave good results in schizophrenia: in particular it shortened the acute upset, and increased the length of remission. Sub-coma was found of particular value in neurosis with physical accompaniments, especially those of the gastro-intestinal tract. Convulsive treatment was found in the Goulburn series to be of great value in depressive states, both of neuroses and psychoses, and in the acute schizophrenic episodes.

Careful case histories were taken of every patient, and an attempt was made to discover any factors relevant in causing mental illness. Investigation of these brought to light some interesting findings and also emphasised the importance of social rehabilitation of these patients. Towards the end of the war a special organisation was set up to deal with psychiatric patients on discharge from the Services, particularly those who had had psychoses or severer forms of psychoneurosis. The ideal arrangement, described by Sinclair, allowed cooperation between psychiatrist, psychologist, social worker, rehabilitation officer, occupational therapist, physiotherapist, education officer and the commander of the patient's unit. It will be noted that most of these persons were carrying out duties whose specialised nature had only recently been recognised. After discharge the patient needed further liaison between the army allocation officer, "A" Branch, the manpower officer, Repatriation Department, employers of

labour, civilian social bodies, civilian hospitals and the Press. That difficulties were encountered was to be expected. Reasonably good contact was maintained with the allocation mechanism of the services, though occasional breakdowns occurred, but the link with manpower was weak, and that with repatriation and civil bodies sometimes broke down. Little help was obtained from the Press, as published statements were not always well-informed; some of these, though no doubt intended to help the men, produced the opposite effect. Much of the publicity given to mental disease has been harmful.

On the clinical side more may now be said of the types of psychosis encountered during the Pacific war. Sinclair reviewed 564 cases of psychotic states in soldiers, and Ross, Curtis and others have also recorded their observations. The usual manic depressive, delusional and confusional states were seen in the large Goulburn series, which fairly represents the experiences of all the services, but the most important was the acute "schizophrenic" disease which occurred in considerable numbers in the later years of the war. Of Sinclair's 564 patients 400 were classified as schizophrenics. This psychosis has attracted much attention, which its importance fully warrants. But it should be realised that if for convenience it is called "acute schizophrenia" it is with some mental reservation. The use of this classification does not imply that the personality is of that peculiar kind associated with the disease usually known as schizophrenia in civil practice. Curtis has suggested that as empiricism cannot be avoided in a good deal of even modern psychiatric work, it is neither necessary nor desirable to attempt to place mental illnesses in categories in their early stages. Action based on immediate needs is preferable.

There is general agreement that prompt energetic treatment is of great value in these acute schizophrenic states in causing amelioration of the patient's symptoms, simplifying his handling, and lessening the distress of his relatives. The later prognosis is thereby improved also, though some of the early enthusiasm aroused by the excellent immediate results of convulsive treatment has not been altogether sustained, for unless initial treatment was followed up relapse was prone to occur.

At Ekibin, from the 102nd A.G.H., Major J. F. Williams reported good results similar to those of Sinclair. He found that very few certifications were required, although the proportion of psychotics among the admissions was high, reaching 30 per cent of one consecutive series of 524 admissions. From January to December 1945, 1,648 psychiatric patients were admitted to this hospital.

The clinical aspects of these acute psychoses were striking because of the intensity of the disturbances of behaviour, which indeed obscured other features. Hallucinations were not a prominent feature, but confusion was common and often severe, and excitement was extreme. No toxic cause could be demonstrated. The clinical picture was not that of the typical schizophrenia seen in civil life, but Sinclair has emphasised that there are closer resemblances than appear on superficial observation. Though the impression given was that of a much more acute onset than

in civil life, he found that a gradual onset was common. At the time of admission to hospital the detachment familiar in civilian schizophrenia was not so evident, but in other features there was considerable correspondence. Sixty per cent of the 400 men in Sinclair's series began their illness with symptoms strongly resembling those of hysterical or anxiety states. Careful observation and enquiry after subsidence of the acute episodes showed that other psychotic symptoms were in evidence, and in 80 per cent of the patients these had been detectable for about one month. A past history of deviations of personality was frequently elicited. Most of the men were of solitary habit; 78 per cent were unmarried, and 30 per cent had poor school records.

An analysis of results obtained from the psychiatric treatment centres was very satisfactory.

A follow-up of psychotic patients from Goulburn showed that 81 per cent returned to their homes; the traceable figure for certification to mental institutions for the series was 4.75 per cent. Later enquiry showed that 69 per cent of the men were working full-time and 7 per cent part-time. It may be that these good results were due to early recognition and treatment rather than to any particular favourable character of the illness. Sinclair reported 292 of 400 schizophrenics as cured, 31 as partially cured, and 13 as having a result which was uncertain: in 262 of these the duration had been only two months or less.

It is recognised that these figures do not represent end results, as it is only by study of the after careers of these patients that any clear idea can be gained as to how they have stood up to the trials and problems of post war society.

Before consideration is given to the causes of psychiatric illness, particularly as seen in the later phases of the war, it is of interest to see what results were obtained in the treatment of psychoneuroses. In the 114th A.G.H. over 3,000 neurotics passed through the hands of the staff. These may all be classed as being of a type severer than average; otherwise they would have been dealt with from other medical units by return to work or regrading. Of this total 1,851 had anxiety states, 755 personality defects, 18 organic disease, 172 hysteria, 156 depressive states and 90 mental deficiency. There were 8 epileptics. Of the total only 153 were returned to their units.

Some of these people were a problem after discharge, just as they are in civil practice. They were sometimes worse after discharge. This was in some instances due to the strain of suspense while waiting at the General Details Depot: elimination of delays was found to be helpful. The men themselves were sometimes resistant: for instance, visits of social workers, who if well trained could be of considerable assistance, were often resented. Even if the importance of workers on the outskirts of the psychiatric field has perhaps been overstressed, there is no doubt about the need for them to be highly trained.

Before we leave the subject of the actual clinical handling of patients suffering from mental disease, the difficulties facing the services in this

huge task must be realised, especially as the average civil medical and nursing standards were not nearly so high in this branch of medicines as in, say, surgery. Diagnosis was far from easy. No period of observation in home surroundings was possible as in civil life—the environs of the servicemen were often a provocation in themselves. Special problems arose in some services. In the R.A.A.F., for example, arose the exceedingly vexed question of the "moral fibre" cases. Was a pilot merely exhausted and over-worked, or was he losing heart? Commanders and medical officers of squadrons had a difficult task in deciding the best action to take with men of intelligence who carried out highly individual technical work, and who had been trained at high cost of money and energy. The psychiatric diagnosis was often difficult to make in any class of patient. Was the man merely anxious? Was he of the unproductive hysteroid type, never likely to be really useful, or was he in the early stages of a psychosis? Examination of figures shows that little reliance can be placed on detailed diagnoses, differing so much with the experience and technical vocabulary of the medical officer.

The physical difficulties and anxieties in caring for the acute mental casualties have been mentioned before. They were often severe. To nurse patients in insulin coma in a camp hospital for instance is no mean feat. To send acutely excited men over a long evacuation route in an aircraft, where fatigue and anoxia will add to their troubles, is a great responsibility. These men would often be classed as severely and even dangerously ill in an ordinary medical ward. Even at the end of the war, when smooth air transport arrangements landed patients in Brisbane within a few days of their breakdown in Borneo, their physical and mental condition often caused embarrassment on their arrival. In parts of Northern Australia the climate could be as exacting as in New Guinea and other tropical islands. Heat effects were often dangerous in excited patients, especially if under restraint. Hyperthermia could and did occur: at least one death took place from this cause. Another medical difficulty associated with transport of patients was the need for labelling them in transit. In ambulance trains particularly, men naturally read the labels attached to them. Psychiatric patients were not necessarily edified or improved by this knowledge: even the use of initials and codes became transparent.

Finally it is not surprising that criticisms were levelled at the medical services. The subject of psychiatry was "news". For example a Returned Soldiers' organisation complained that psychotic soldiers were suffering because of lack of trained male mental nursing orderlies. There was a shortage, just as in every other skilled occupation, and orderlies under special training were used just as trainee nurses are in all hospitals. Where additional help was available from trained orderlies, as at Ekibin, where a number of skilled men were lent by the Royal Navy, this was greatly appreciated. Perhaps it might have been possible to find more trained men in the armed Services had occupational analyses been possible at that time. Unfortunately there had been great delays in installing statistical

machines, owing to difficulties in obtaining financial approval, and consequent wastages in manpower occurred.

Even within the armed Services lay critics expressed ill-founded ideas, as when the Inspector-General of Administration advocated segregation of "neurotics" from ordinary service patients so that they might have specialised treatment. The Director-General of Medical Services pointed out that segregation was practised where necessary, that many patients were better treated out of hospital, and although mental specialists were limited in number, general physicians of wide experience were also skilled and successful in the treatment of neuroses. It is obvious that such criticism is based on the belief that neuroses occurring during wartime belongs to an order *sui generis*. It is probably indicative of the views of the community in general.

THE CAUSES OF PSYCHOSES

In discussing the aetiology of psychiatric affections it is preferable in this instance to defer a general consideration till the last, and to examine first certain special features peculiar to the Pacific campaigns. The later stages of the war in the islands marked a period in which the community was exposed to the increasing strain of a long war. More and more men and women were involved, severe stresses were imposed on the spearhead of the forces concerned, yet there was an ever lessening national risk to Australia. It is of interest therefore to examine more closely the possible causes for the rising number of acute psychoses, and then to consider the general position of psychiatric disturbances of all kinds in the whole community.

During the Pacific war the decreasing importance of volunteer selection of the smaller forces of earlier years may be noted. Fitts had previously pointed out that it does not follow that lower figures for psychoneuroses should be expected in a volunteer force, which includes those wishing to escape from private difficulties, the emotionally unbalanced, who soon lose enthusiasm, and those who withhold information about their health. Sinclair could find no difference in incidence of psychiatric disturbances among volunteers and conscripts. His figures comparing the civil and military incidence of schizophrenia are interesting. The average rate for 1943-1944 in the army was 0.468 per thousand: the comparable rate for males between the ages of 20 and 35 years admitted to the public and private mental hospitals of Victoria was 0.503 per thousand. The latter figure is probably understated, as all civil schizophrenics do not go to hospital. If we assume accuracy of diagnosis, it thus seems fair to deduce that war has not increased the incidence of schizophrenia in the community as a whole. Yet the increased incidence in the later war years needs an explanation. It is curious that the rate in the army fluctuated considerably. It was highest (0.703 per 1,000) at the end of 1944 when the battle commitments of the troops were less heavy than during the periods before and after this date. Investigation showed that only 42 per cent of the patients came from combat zones, and that in only 3 per cent

of the cases could the precipitation of a psychosis be blamed on combat stress. In 244 of the Goulburn series of 400 no history of special combat stress was obtained. Average stress was experienced by 108 patients and severe stress by only 39. In his New Guinea series Sinclair estimated that psychoses and neuroses had their roots in pre-enlistment conditions in 34 per cent, that they were accentuated by war service in 51 per cent, and that they were wholly attributable to war service in only 14 per cent of cases. Some analysis of the military situation at the time of breakdown was attempted also; this seemed to be relevant in 110 cases, whereas pre-service conditions appeared to be of greater importance in 199, and a combination of factors in 42. Study of the individual patient's past history and personality confirmed the view that this psychosis tends to arise in persons of the schizoid type. Evidence of this has been previously outlined. The impact of service life on the solitary individual is probably more concentrated and severe than that of life as it meets and envelops the young civilian. Age had some selective influence, as has been shown, but more in determining acute psychoses than in neurotic disturbances in general. The drawbacks of an unsatisfactory background are undoubted, and it must be admitted that in the rapid expansion of the forces in 1942 many unfits were accepted for service. Illness was found to be significant in some series of psychoneuroses, as in Tobruk; wounds had little influence, but in general physical illness does not appear of aetiological importance. Domestic and sexual maladjustments were not of themselves found of major importance, though as part of an unfavourable background they were of significance. The loyalty, steadfastness and cheerfulness of women folk at home were of the highest value to the soldiers' morale.

Possibly further light is shed on the rising incidence of acute schizophrenic states in the army by the experiences of one area. The sub-base hospital at Lae and holding units farther north of Aitape both felt the strain of these increased numbers. These were drawn from a force engaged in the later New Guinea campaigns in which the task of the Australian troops was the elimination of the remaining Japanese from areas which were already lost to the armies of Japan. This applied to the Aitape-Wewak and Bougainville operations. The most striking medical episode of the former operations was the epidemic incidence of malaria, which is dealt with fully in the section on malaria. Though there is no causal relation between malaria and the onset of acute psychoses, it is possible that there may have been some similarity in some factors leading to a breakdown in malarial control and those predisposing to psychogenic illnesses. At the time in question, the early half of 1945, psychoneuroses were prevalent among the troops in the forward areas. Despite an apparently high military morale and a successful performance, there is reason for believing that frustration was felt by these men.

During the earlier difficult campaigns there were comparatively few acute psychiatric casualties, though for rather brief periods severe combat stress was in evidence. In any case, psychiatric experience does not indicate that battle stress was of itself a significant cause. But these "mopping-up"

campaigns, such as that carried out by the veteran 6th Division, had already raised some uncertainty in the minds of the troops and other more remote critics of their necessity. Undoubtedly the subject had been widely discussed.

In addition, the anti-malarial discipline and restrictions placed on the troops were strict to the point of harshness, though they differed in no essential principle from those imposed earlier. There was evidence too that these strains and those imposed by the continuance of a long war in an uncomfortable place were felt severely by the young men.

Turning to the wider aspects of the predisposing causes of psychiatric disorders, it is perhaps simpler to speak in general terms. The boundary between neuroses and psychoses has become more indefinite of recent years, and it is natural that in service practice uncertainty was often felt as to the diagnosis. A depressive neurosis might need the same symptomatic treatment as a depressive episode of a manic-depressive syndrome. Prognosis from the service point of view was often simple, but from the point of view of a civilian career it might be most difficult.

The wastage in the Services from mental disorders of all types was great: it is also great in the civil community.

CONCLUSION

In armed forces at war it is the duty of the medical services to bring clinical science to the individual, even in such matters as mental security. In military psychiatry Australia was at first unprepared, and the number of thoroughly trained experts was small. In the early days the extreme reactionary doctrine was voiced by those who trusted junior and relatively inexperienced unit medical officers to "detect the malingerer and bash back the neurotic". Gradually more confidence was shown in psychiatric advisers, but more help by consultants expert in this work was needed in medical units, particularly those in forward areas. There was some fear that over-enthusiastic psychiatrists might start a landslide which might sweep away a goodly proportion of the essential manpower through a broadened channel leading to the way out. Such exaggerated fears hardly did the psychiatrists justice. Towards the end of the war the psychiatric service became more adequate, and much good work was done by the exponents of a specialty somewhat of a Cinderella in Australia. The greatest need of all was probably the influence of experienced consultants who could teach by example, circulating through the forward units of the forces, helping to solve problems, learning for themselves how the men lived, and acting as educators in a field where so many felt unsure.

The special constitution of medical boards for psychiatric cases, the admirable hospital services established and the care given to the mental side of rehabilitation all demonstrate the influence of psychiatric medicine on the medical services of all arms. Military considerations also reflect upon the causes of mental disorders in the civil community. Speaking in the most general terms, influences stretching back into childhood are probably of more significance than recent or present domestic or social

maladjustments: the former may supply the key to the latter. Regression to childish or even infantile behaviour was not uncommon among psychoneurotics in the services, and was probably as significant as a history obtained by analytical interviews. It was dependence rather than independence that hastened the downfall of such individuals. This brings us to think of the conditions of life in the average modern community and to consider what bearing the inter-relations of men with their surroundings have on their capacity to adjust themselves to a state of war, even apart from the risks of combat.

The vast conflicts of the last two generations and the accelerated social changes of the same period have altered the contemporary life of peoples not yet conditioned to their new environment. Even social amelioration is a paradox, inasmuch as it increases man's dependence on a highly organised and artificial society. Men now rely on the State as an indulgent parent, and in proportion, while resenting control, become less able to take independent action. Aggression arises as a by-product of frustration, and the result is anxiety, or even some striking manifestation of mental maladjustment.

It would seem that the mental problems of the communities of the world are now so deeply serious that it is difficult to see the way of escape. Certainly an increase in psychosomatic and psychoneurotic disease, in other words, mental disease, seems likely. It is only necessary to review world history of the last century in the most cursory fashion to see that the most laudable efforts to effect social amelioration may produce also tensely unfavourable social conduct unless these benefits also help communities as well as individuals to attain mental equilibrium. Man is a relatively adaptable creature, but the tempo of his adaptability has been sadly overstrained. In an army a group of men thought to be mentally stable may show neurotic signs because of the collapse of the foundations on which they have built and trusted: an unstable group, even though intelligent and earnest, may fail because of frustration. The same may happen and does happen in civilised communities. Today particularly the primal instincts of self-preservation and self-reproduction are not fully satisfied, and social unrest is inevitable. These are the problems we have to face. The medical profession has a definite responsibility in the recognition, treatment, and prevention of mental illness. Specialties in medicine have a dual function, that of carrying out skilled work by special methods, and that of adding to the general store of knowledge necessary for all well equipped practitioners. They should guide but not dominate. This applies with particular force to psychiatry. War experience has emphasised the growing significance of the mind-body relationship, and the need for keen appreciation of the importance of mental health to individuals, to groups and to nations.

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CHAPTER 61

MEDICAL REHABILITATION

"Where is the penny world I bought?" (T. S. Eliot)

No clinical account of illness or injury could be truly complete without at least some brief notice of the medical measures taken to help men and women back to a functional life. The subjects of the medical aspects of rehabilitation or re-enablement, and the accessory organisations of physiotherapy and occupational therapy will be treated more fully in another place, where the story of their rise in importance and recognition can be told. Convalescent depots and homes, or, as the air force more accurately called them, rehabilitation units, were planned more thoughtfully during the war and their work was dovetailed into the earlier remedial work of hospitals.

It is not easy to escape from "that flat swamp of convalescence left by the ebb of sickness", as Charles Lamb called it, "far enough from the *terra firma* of established health". In the vast enterprise of war considerable organisation was needed to provide the necessary services and to inculcate the correct attitude of mind of those working in the therapeutic field both before and after the soldier's discharge. We are not in this history concerned with the great responsibilities of the Repatriation Department, but in this instance only with the efforts of the medical services of the armed forces to re-enable the men who had fallen out through sickness or injury and had to pick themselves up while others went on. Those who recovered with a lowered standard of physical or mental fitness presented a more difficult problem, and as the end of the war came in sight there loomed the still greater difficulty of bridging the gap from war to "peace". The re-enablement of the sick could indeed only be carried out, even with reasonable success, if the correct policy was realised by anticipation and action from the beginning.

Much more interest is now taken in the provision of facilities for rehabilitation in the civil community, and much more is needed to ensure active collaboration between the various groups of workers, medical, social and industrial, who can combine to this end.

In the army, greater emphasis was laid on accessory services, particularly physiotherapy and occupational therapy. These began by striving for recognition in concrete form as an organised body, and established a valuable linkage between physician and surgeon on the one hand, and educational and other non-medical workers on the other. The growing influence of psychiatry, especially in the expanding clinical contacts of its exponents, stimulated further interest in the important, perhaps all-important mental aspects of illness.

Lieut-Colonel J. D. Galbraith, Director of Rehabilitation at the close of the war, pointed out that "the keystone of therapeutic rehabilitation

is the medical officer" and that the team of workers must include physiotherapists, occupational therapists, teachers of diversional activities, physical instructors, education officers and medical social service workers, together with a coordinating staff. This organisation was applied to the terminal problems of rehabilitation in the Services, up to the point of their transference to the Repatriation Department, but the same principle on a smaller scale applied to the similar work which went on throughout the war in all larger medical units. A special rehabilitation officer was appointed in each unit to cope with the special medical problems of demobilisation in the latter stages of the war. His value depended largely on a personal factor and the same could be said of any medical officer in his daily duties, in the discharge of which he had always to look to the end.

Rehabilitation as a vital aspect of medical units called for physiotherapy and occupational therapy in particular. In the Middle East a special physiotherapeutic unit was established at the 2/2nd A.G.H. at Kantara, working with the orthopaedic unit and other branches of the hospital. Physiotherapists in the beginning were known only as masseurs and masseuses, but after not a little opposition a proper status was accorded them, and finally in 1944, a Chief Physiotherapist was appointed to the staff of the D.G.M.S. at the Australian Army Medical Headquarters, under the control of the Director of Surgery. The work done by this branch of the service covered not only active treatment of appropriate conditions of limbs and joints but also of the chest, and of injuries treated by plastic surgery. Without skilled physiotherapists, the application of plaster casts by surgeons would have been much less rapid and efficient.

Occupational therapy as a skilled ancillary branch of medical treatment also had small and difficult beginnings, but eventually attained separate recognition under a controller, and working with medical officers helped and coordinated work over a wide field. One prejudice which had to be overcome arose from confusion with purely diversional therapy, which though useful, supplied in the main a relief from tedium. The very small number of trained occupational therapists was increased by training others, and much was done towards the social adjustment of patients. Medical officers from surgeons to psychiatrists found this skilled assistance most valuable.

All the organisation which had gone before helped to energise the medical enablement of many who faced demobilisation. Clinical medicine extends beyond the patient's bedside in its interests, taking in his background and his expected future. Therefore rehabilitation, in looking forward from the earliest mutual contacts of physicians with the sick, has its place in the clinical problems of war. A man is not well unless he is physically and mentally integrated to his world, and even if he finds the world to which he returns after the strange interlude of war service has not the domestic familiarity of the "penny world" that once filled his needs, he may yet be helped to adjust himself and be content. At the least to quote Arnold Bennett: "Happy? Well, not unhappy".

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EPILOGUE

We have seen what applied science could do to alleviate the suffering and lessen the wastage of war, and to make advances in knowledge which may help peacefully disposed peoples in their fight against the enemy Nature. To gain these ends required a complex and disciplined organisation, flexible enough to allow individualism more play than is possible with those who are soldiers by instinct or training. Now, after the conclusion of active fighting, there are two serious questions to be answered.

The first concerns the organisation of medicine in peacetime for the good of the community. Social and industrial medicine are already firmly planted growths in well ordered communities; they follow the call of both science and humanity. That much more is needed is universally recognised. The problem is to find how this can be done without sacrificing standards of work, and without stirring to wakefulness the lightly sleeping demons of avarice, slothfulness and strife. It is a paradox of the modern State that as the citizen receives, and rightly receives, greater benefits for himself and his children, so his life is more bond than free. With the circle of individual action ever narrowing, by inexorable psychological law he becomes more frustrate, and therefore more aggressive. This is well seen in service medicine. It diffused benefits so wide and free that it almost caught up with the new deviltries of man himself, but no doctor in an armed service could fail to discern at times a certain hostility in his patients, except during the chastening rigours of illness. His duty was to keep men well, and to treat them promptly and efficiently when sick or hurt, but he was often forced to seem hard when he was merely loyal and realistic. In other words, the normal individual relationship of doctor to patient was often difficult to preserve. Already there are signs that these ties are slackening in civil communities. It seems unlikely that the physician-priest will ever become extinct, but is there not a danger that he may become obsolete?

The second question directs our mental gaze to the beckoning finger of science. During the years of war we owed a vast debt to science, with whose gifts we wrought not only good but evil. In the war story of the medical services the need for scientific direction is apparent; so too is the need for humility. But now we know we cannot go back, and in going forward whither are we going? Even in the field of medical science shall we go on and on to more rarefied atmospheres of applied knowledge where humanity with its warm spiritual metabolism will faint and die? Science is not enough, nor will it avail to invoke the restraining hand of history and experience. Man is blind to experience, and deaf to history. As always he is intoxicated by power, and the new heady brews of scientific method are leading him more and more to destroy, not only by the physical violence of wrecking and killing, but by the moral violence

of suppressing and denying the true culture of mind and spirit. Should we not look to ends rather than to means? Nothing but a change of heart can do this, for it is a question of spiritual values. The doctor is still a champion of the individual; he stands at the springs of life and death in peace as in war, and as a citizen he must accept this challenge.

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